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PROCEEDINGS

ENGINEERS' SOCIETY
OF
WESTERN PENNSYLVANIA

VOLUME XXII

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PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXII FEBRUARY, 1906 No. 1

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

*PRESIDENTIAL ADDRESS.

† SAMUEL DIESCHER.

Looking backward to the time when I began work in this country as an engineer, which was forty years ago, I find many things different from what they used to be. Pittsburgh, although quite an old city at that time, was not much known or mentioned in other places; her industries were few but quite formidable for their period; of course in comparison with what is considered large to-day they would appear rather small. A blast furnace of fifty tons capacity per day was something to be admired, for most of the furnaces then in action produced less than that quantity. As late as 1880, it was found worth while to spend money on increasing the output of the once well-known Red Bank furnace, up the Allegheny Valley, from 22 to 25 tons of pig iron per day. That furnace was built square, of rubble masonry, and bound together by timbers and iron tie rods. Now it is out of existence, it disappeared entirely.

In those times, labor saving devices were looked upon with suspicion by both employer and employee; in fact, it was very hard to induce anybody to adopt improved methods, the old way of doing things by hand was considered the only way to be relied upon. At the skelp mill in a tube works in this

* Annual Meeting of the Society, January 4, 1906.

† Farmers Bank, Pittsburgh, Pa.

city, five laborers were constantly employed to handle the skelp as it went in and out of the rolls, and drag it from one stand of rolls to another, and finally to the cooling bed. In response to remarks I made as to the feasibility of substituting mechanical means for the laborers, the manager said: "We have done it this way ever since I came here and that is now twenty-four years; the owner is satisfied with it and so are we, hence there is no need of making a change."

There were also a number of oil refineries here; however, during the seventies they gradually disappeared, most of them being transplanted elsewhere.

The glass industry was quite formidable, but did not yet produce plate glass as used for show windows, mirrors, and the like. The tank furnace was adopted only within the last fifteen years; since then, various machines have been invented for the production of specialties. They work automatically and need no skilled attention.

Coal was mined entirely by handwork; the mining machine was introduced during the seventies, about the time of the Centennial exposition. But in this case, as in every other, the adoption of machinery in place of hand work was opposed with all the energy prejudice and obstinacy are capable of.

Slack coal at that time was practically worthless, for the price it would have brought would not pay the freight, therefore it was simply thrown away and let burn, provided that there was room to spare about the mine or tipple, otherwise the owner had to pay for having it hauled away. As late as in 1881 a coking plant located above West Elizabeth, on the Monongahela River, bought slack from a mine on the opposite side of that river and paid ten cents per ton delivered in flats at the coke works. Thanks to the introduction of mechanical stokers, the use of slack coal is on the increase because anything larger than nut coal won't pass through the stoker. The employment of such a device in firing boilers affords another illustration of the superiority of regularly working mechanical means over intermittent, irregular, and often careless hand labor. If the smoke nuisance is ever to be abated

while boilers are being fired with coal, the mechanical stoker must come into general use.

For engineers there was little employment to be found, excepting in field work. The products of the machine shop were not of great variety; almost every machine shop had some specialty that it made over and over, and in addition to this it took any work that happened to be brought there. Complicated things were always referred to the boss pattern maker who, as a rule, was the genius of the establishment. Many a shop built its own lathe, planer, drill press or engine; the building of engines as a specialty began only with the demand for higher efficiency, that is, reduced consumption of fuel, for while in determining the dimensions of power plants of given capacity the rule followed was that sixty pounds of water and ten pounds of coal are required per hour per horse power, there was no inducement for special efforts in designing and building high grade automatic cut-off engines. The fact is that in the sixties there were more Corliss engines in operation on the continent of Europe than in the United States, yet that engine is an American invention.

The former Moores' Locomotive Works in Cincinnati, O., built locomotives, as its name indicates, yet there was no draftsman employed in that establishment, nor was there a necessity felt for drawings to work by. Every mechanic that produced a part for a locomotive fitted it on as well as he could and let the next man see for himself how he would get his work in. The once much-discussed Shields pumping engine in the Cincinnati water works, was built without any systematic design; the engineer intrusted with the construction of that machine took a piece of planed board, drew on it the outlines of the cylinder, handed it to the pattern maker with the order to make the pattern, and as the diameter of that cylinder was one hundred inches and the stroke proportionate, it kept the pattern shop busy for several weeks. Thereafter, another piece of board was covered with the outlines of another detail, and so on until eventually the whole machine had been gradually put on boards. Towards the

completion of the machine the city councils appropriated the sum of five hundred dollars to get a complete drawing made; with this task a local patent solicitor was intrusted, who made a very artistic perspective picture of the engine.

Municipalities and railway companies considered the engineering department as an unavoidable evil, a mere cause of expense, that ought to be dispensed with whenever possible. In harmony with that notion the engineer's office was usually relegated to the loft or some other out-of-the-way place that no other department would want to occupy. By and by the usefulness of the engineer's services was more recognized; he was treated with more consideration, given better quarters and pay. At present on some of the most important railways of the United States the highest officers in the department of administration are experienced engineers, because it was found that a man thoroughly familiar with the construction, maintenance, and operation of a railway is better equipped for the management of it than a man with only a commercial or perhaps no particular education.

Prior to the introduction of the modern steel processes, little progress was made in the iron industry. The whole business was pursued according to long standing custom; this was radically changed with the advent of the Bessemer process, for in this the old ways and methods had to be abandoned and the chemist had to be called in so as to get the desired results. Since then, the chemist is the important man in the production of steel for the many different purposes; in fact he is the guide in the entire field of modern metallurgy.

With the introduction of Bessemer steel for rails, bridges, and structural work of all kinds there came also a greater demand for the engineer's work; because this new material permitted the construction of bridges of much longer spans than formerly, giving a general impulse to the substitution of steel structures for those of wood. Rails made of Bessemer steel had a greater carrying capacity, and stood more wear than those of iron; this feature permitted, in turn, the use of much heavier rolling stock. All this contributed to the carry-

ing capacity of the railways and resulted in a noticeable decrease in the dead weight moved in proportion to the paying weight. Simultaneously with the advent of Bessemer steel came also a general improvement, that is, the enterprising spirit all over the country awakened; large capital was invested in the manufacture of all kinds of commodities, and plants already in operation increased their capacities to meet the growing demands on them due to the prevailing stimulus in commerce and trade. All of those events had their influence upon the opportunities of the engineer, no matter in what particular line he may have been active. The general prosperity caused a growth in the population of the country at large and especially in the centers of commerce and trade. The increase in the population of the cities again demanded new and more adequate means of transportation between the business centers and the suburbs. This gave cause for the construction of the cable railways and, eventually, of the electric railway; this latter type of transportation meets the requirements so satisfactorily that it promises to stay unless some other very remarkable discovery is made that will exceed electric power in its adaptability to this purpose. That, in the course of time, such change will occur nobody can doubt who considers what astonishing things have been discovered during the recent years and subjected to the service of man. Experience of late years shows that no matter how satisfactory at the time being an innovation may be, it will be displaced before long by something still better.

With every step forward, arose a new demand for engineers, and with it another specialty, for now-a-days any subbranch of engineering requires the full attention one can devote to it, because the deeper one enters into its nature the more he finds there are things in it that need still further study.

An entirely new line of engineering is Electrical engineering. It thanks its creation to the many important discoveries made during the last three decades. At the time when I attended the lectures on physics, electricity was used

almost exclusively in telegraphy and stereotypy, beyond that it was considered a very interesting subject for study but of little further practical value. What a difference between then and now! I remember well when at the lecture on experimental chemistry the professor showed us a medallion about the size of a silver dollar, it was aluminum; he let us handle it, too, which we considered quite a treat, for it was then a rare metal and dear, few people had the good fortune of seeing a piece of it; now it is produced by the ton. It is used for kitchen utensils and all manner of things. This branch of metallurgy could not have been brought to its present state of perfection without the help of electrical engineering and chemistry combined.

Electrical engineering, the youngest branch of our profession, has within the short space of its existence achieved most wonderful results and pressed its mark upon industry, transportation, commerce, and on the comfort of the individual as well as that of the masses, and according to indications, has by no means reached its full development. Further surprises may be looked for within the near future, of the nature of which we can not form even a conception. We are already enabled to communicate with people hundreds of miles away by word of language and by sound signs, yet without visible connection between those points. What may we not expect from that source? Every single discovery in the workshop of nature widens the vision of the searcher, reveals unknown laws and equips the investigator to still better penetrate the depths of nature's secrets, and make new further discoveries all of which in one way or another advances man's moral and intellectual progress, his welfare and happiness, and where is the limit?

The great capital now invested in all kinds of enterprises caused everything affected by it to grow in proportion. Look at the skyscraper. It is safe to state that in the Frick and Carnegie Buildings in Pittsburgh there is more business transacted than there was forty years ago in all Western Pennsylvania. Everything around us is of larger dimensions.

Look at the plants of the United States Steel Corporation, the American Bridge Company, the Westinghouse establishments, and others, all of them monuments to ingenuity. The masses we lift and transport now-a-days with ease and speed were in the times referred to considered practically immovable within reasonable time and with the means then known. Instead of putting a gang of men to shovel out the contents of a freight car, we now pick up the car bodily, upset it, and dump its fifty tons of ore, coke, or coal in fewer minutes than it would take fifty men hours to empty it with shovels. In large excavating work we employ powerful machines to scoop the earth by yardfuls at each movement of the machine, in place of picking and shoveling. The equipments of shops, mills, and factories were also improved in harmony with other things. There the heaviest modern freight locomotive is lifted and carried above the heads of the men to any part of a building. The power for this remarkable performance is furnished by an electric motor—a device not at all known forty years ago. This same device also supplanted transmissions, belts, and pulleys in machine shops, mills, etc., by its direct attachment to the machines to be driven.

Chemistry too advanced to a degree that compels admiration. Also in this branch of natural science discoveries were made within recent years that are as wonderful as those made in electricity. Metallurgy in all its branches is now carried on in strict accord with the teachings of chemistry. It contributed in a very large measure to the stock of human knowledge and the general progress of mankind.

The more we look backward the more we get convinced that the ascendancy and permanence of our profession keeps pace with the progress in the study of nature. With the advance of science the scope of the engineer's activity widens also, for every discovery in the realm of nature soon finds application to a practical purpose, and here it is where the service of the engineer becomes most conspicuous by making such application practicable. But in order that he be able to fully answer the demand on him, he must continually

co-ordinate himself with the successive stages of scientific progress and so augment his theoretical equipment as not to be out of date with his surroundings. The more that is learned about nature, her laws and forces, the greater becomes his need for a thorough theoretical training. The old saying that a thing may be right in theory but wrong in practice, is a fallacy, because theories the engineer deals with are not arbitrary products of the human mind but laws of nature, and, as such, necessarily perfect; but frequently a theory is only partly known and partly assumed, it stands to reason that a structure built upon such a foundation is apt to collapse.

The activity of the engineer, meaning all the various lines constituting the profession in its entirety, makes man's life easier, healthier, and more comfortable. It dispenses with health destroying occupations, increases man's powers and with them his opportunities to get on in the world. By reason of the many discoveries made within the last few decades, man's effectiveness in his daily pursuit is several times as large as it was a generation ago; this fact is clearly seen if we consider the various means at our service for saving time and effort and for reducing distance. Due also to the efforts of the engineer, the modern methods have so reduced the cost of production of many commodities that they come within the reach of the working man whose parents were not able to enjoy them, although wages are practically the same now as then, but the difference is in the higher cost of production in former times.

What many centuries with so-called purely classical education could not accomplish in civilizing and humanizing results, the universal and unhampered pursuance of the study of natural science brought forth within the last half century, and the conversion of the purely scientific results to the practical needs of mankind is the task of the engineer. This duty conscientiously performed is in itself a source of satisfaction and must compensate the engineer for what he lacks in opportunities to get rich, for in the end there is no acquisition of

wealth so satisfactory as that which results from one's own exertion.

The unprecedented profits some of the large entertainprises yielded within recent years induced a class of men, conspicuous more by their cunningness than integrity, to conceive dishonest schemes by the launching of which they succeeded in depriving other people of their own, and thus acquired fortunes entirely too large for their intellectual fitness to properly use such wealth. This event has its demoralizing influence upon the present generation which seems to get under the impression that after all it is not a shame to be dishonest, provided one is so to an extraordinary degree; and as bad examples spoil good principles the tendency to get rich quick prevails very generally and is exploited according to opportunities. This is a matter that, strictly speaking, does not belong before an Engineer's Society and should perhaps not be mentioned here; however, I feel induced to remind my young fellow professionals that if the engineer is to hold his proper position in the estimation of his fellow citizens, which is that of unreserved trust, he must, besides being learned and skilled, be a man of strict integrity, for no man or corporation will intrust an engineer with the planning and execution of a costly project, or with the management of an existing establishment, unless there is satisfactory reason to believe he is proof against the temptations the opportunities of his position bring with them.

*POWER REQUIRED BY MACHINE TOOLS, WITH SPECIAL REFERENCE TO INDIVIDUAL MOTOR DRIVE.

† G. M. CAMPBELL.

Member.

This article will not be a theoretical exposition of the subject in general but will rather present a few deductions from the various motor equipments in a modern shop, giving certain curves of power in connection therewith and various examples of every day practice in these shops. Most of the inferences that may be drawn from these records will be left for the reader to make as he sees fit.

There has been a large number of articles written on the amount of power required by machine tools, some of them of but little service but others of the very highest value, and in these articles the horse power required by certain machines varies greatly. This is as might be expected. A certain machine tool, if used to the limit, would require the same horse power in every case, but the same machine in different shops is used for different purposes; in one shop it might be used only for course roughing cuts whereas in another it might be used wholly for light finishing cuts; the horse power requirements would be widely different. It is thus necessary to study the special conditions in every instance. In general shops where practically little is done except repair work, such for example as locomotive repair shops, small jobbing concerns, etc., the size of motor required is smaller than would be required for the same tools in ordinary manufacturing shops, and motors in these again would be smaller than would

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* Meeting Mechanical Section January 9, 1906.

Pittsburgh & Lake Erie R. R., Pittsburgh, Pa.

be required for similar tools in large manufacturing shops where the output may be considered practically raw material, but where a certain amount of roughing work is done, for example, mills whose output is car axles, rough turned shafting, armor plate, etc. Tools in such plants would have relatively large capacity motors.

In machine tool work speed variation is essential, and in a machine driven by an individual motor part of the speed variation must be obtained in the motor itself if efficient speed control is required. The range of speed required in some machines may be quite limited, on account of the particular class of work for which the machine is used, and in such a case the full range of speed could be supplied by the motor. On the other hand, the speed variation required may be so great that it is impossible to supply it all by the motor. For example; the 90 in. lathe referred to in Fig. 4 has spindle speed ratios of about 21 to 1, and the 20 in. lathe referred to in Fig. 5 has spindle speed ratios of about 27 to 1. It is therefore necessary to get this speed range changed by proper gearing into such steps that the whole range in each step can be obtained in the motor. In the 20 in. lathe referred to, four runs of gears were used, three changes being necessary to get the total range of 27 to 1 in spindle speed. Calling these gear runs A, B, C, and D; run B would give a spindle speed about three times A; run C about three times B and run D about three times C.

This jump in speed of 300% in each case is of course inadmissible if taken in one jump, therefore the motor is given a speed variation of about 3 to 1. The machine is running with run of gears A and the motor is at its initial speed, then this speed is gradually increased by any desired increment until the motor is running at about three times its initial speed. At this point the gear run is changed to B and the motor dropped back to its initial speed, the machine spindle would then be revolving at about the same rate as on the top speed run A. A similar change is made to C and to D so that

the complete range is obtained in gradual steps with small increments.

Just what range of speed is required in the motor cannot be definitely stated for all conditions. If a total speed range of 6 to 1 is required in a machine, it might be advisable under certain conditions to obtain this total range in the motor, but as a general rule the writer believes it would be advisable to use at least two runs of gears when the speed change required exceeds 4 to one, and that a somewhat better and more efficient design can be obtained when the speed change required in the motor is limited to about 3 to 1. The larger the speed range the larger the motor as is shown in Fig. 2, and of course the greater the price, also the disproportion between size of motor and size of machine increases.

The controller necessary to enable the speed change to be obtained in proper increments will vary according to the range required and the size of the increment. It is feasible to work to within 10% change of speed and consequently a 10% increment would be desirable. If 10% increments are used the number of points of the controller would be obtained from the formula:

$$1.\ 1^{n-2} = \text{Speed range in motor.}$$

Where n is the number of points in controller, "off" point being counted as one point. This would give results as follows.

Speed Range.	Controller Points.
3	14
4	17
5	19
6	21

If the motor is a reversing one, then to this number of forward motion points must be added the required number of back motion points; usually one third to one half the number of forward, so it is seen that the controller would become unwieldy in size or the speed increment would have to be

increased above 10%. In the P. & L. E. shops the speed increment was about 10% and the speed range required in the motor somewhat less than 3 to 1, the necessary number of runs of gears being used to give the total range in the machine. The maximum number of runs used was four.

This speed change in the motor, which is such a requisite for individual motor drive, may be obtained in several ways, the three principal ones at present being:

Multivoltage or four wire system.
Two equal voltage or three-wire system.
Single voltage or two-wire system.

The proper treatment of these various systems would require a paper in itself and cannot be dealt with here. In all the systems the size of motor required is about the same. For certain classes of work one system may be better than another; for reciprocating machine tools, for instance, the multivoltage system is undoubtedly advantageous. Another very strong point in favor of the multivoltage system is that standard motors are used, so that repairs can be easily made without danger of mistake in mixing armatures and fields. This system, however, labors under two disadvantages; First, the power house machinery and the distribution lines are somewhat more complicated than the other systems, but though this is a disadvantage it is very greatly overestimated; Second, it is comparatively inflexible compared to a two-wire system. Any two-wire installation already in service can incorporate without any trouble any number of variable speed single voltage motors, whereas before a single motor operated on the multivoltage system can be put into service, a three part balancer, or motor generator set, has to be installed and also special wiring from power house to motor. This is a great disadvantage and one almost fatal to the expansion of multivoltage control. The three-wire system is a cross between a multivoltage and a two-wire, with part of the good points and part of the bad points of each. At the P. & L. E. shops the multivoltage system is in use, and at the time it was installed, 1902-3, it was undoubtedly the best system on

the market. It has fulfilled all expectations and gives accurately the speed control required, and, owing to the substantial manner in which it was installed, has been maintained at a minimum cost. As to the future, the writer is of the opinion that the single voltage system will predominate.

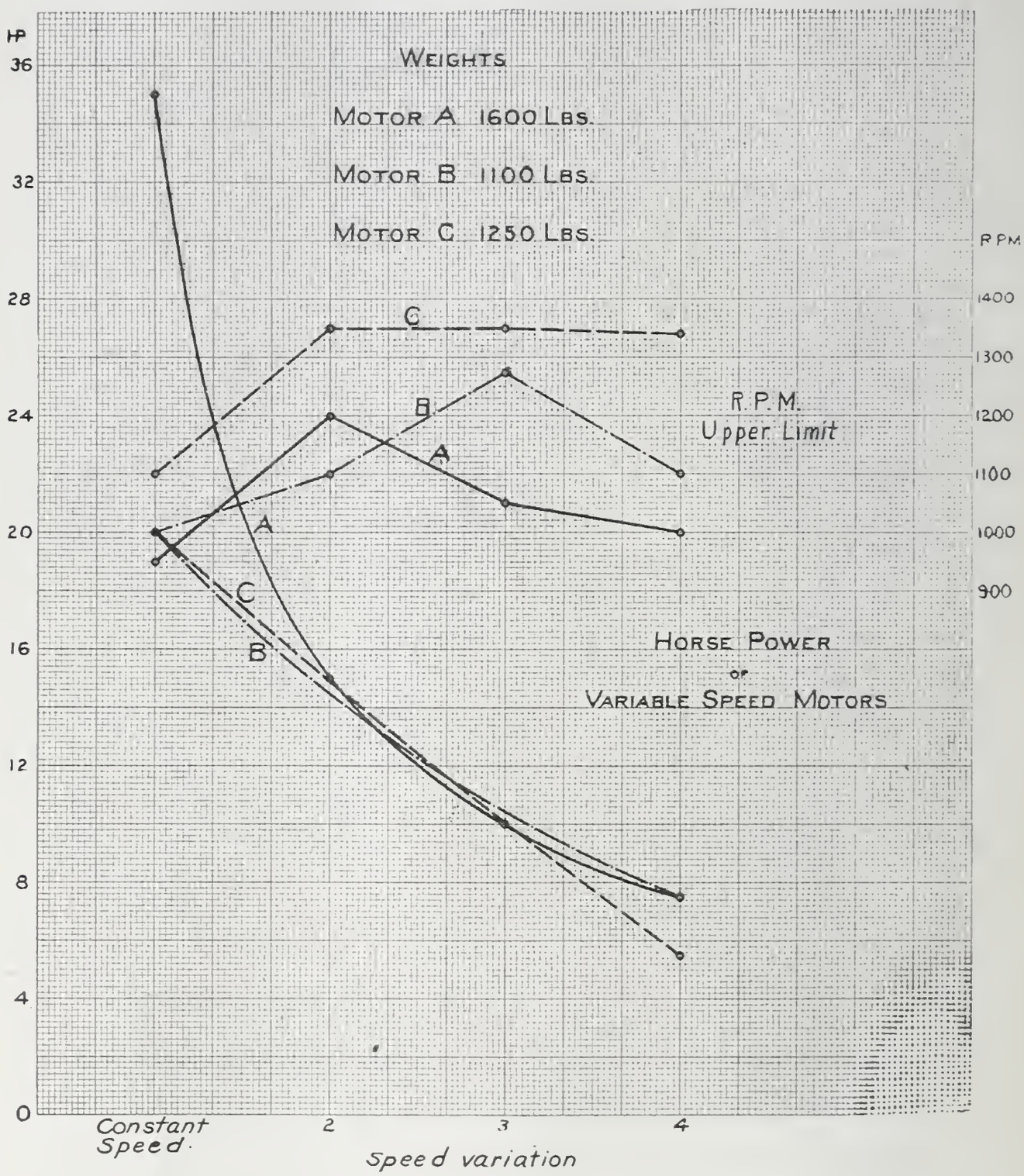

FIG. 1.

One factor which has a decided bearing, not on the amount of power required by the tool but on the power or size of the motor to be provided, is the variation in speed required. In determining the size of the motor for a variable speed machine, it must be borne in mind that as the speed range increases the size of motor also increases for a certain horse power output throughout the range and it must be distinctly understood that a 5 horse power motor with a 2 to 1 range of speed is an entirely different motor from a 5 horse power motor with a 6 to 1 range of speed. Manufacturers advertise that they can provide variable speed motors with a speed range of, say, 5 to 1, but they do not at the same time state that they provide perhaps a 30 horse power motor frame and mark it 5 horse power, that is they provide a size of motor which under ordinary conditions of voltage, field and armature winding would provide 30 horse power with the standard rise of temperature on 24 hour service.

As an example of this Fig. 1 is given showing the rating for variable speed motors built by three different companies. All three motors are for use on a two-wire system with speed control by field resistance; motor B is an interpolar motor. When running as a constant speed motor, motor A has a capacity more in proportion to its weight but the drop from 35 to 15 horse power when a 2 to 1 ratio is required is very great, whereas, in the other two motors the drop from 20 to 15 is proportionally small. Motor A would be sold to one customer as a 35 horse power constant speed motor and to another as a 7½ horse power, 4 to 1 variable speed motor, but the two prices would be practically identical.

If, on the other hand, a certain horse power is required then from Fig. 2 it may be seen how the weight (also the price though not in the same ratio) will vary as the speed variation changes. When the motor is to run at constant speed a 5 horse power motor, of a certain make, curve A, would weigh about 360 pounds without rail base or pulley, whereas the same capacity motor but with a speed variation of 5 to 1 would weigh 1,600 pounds, being then the motor

given by curves A and B in Fig. 1. Curve B is for the same capacity interpolar motor, of another make, weight ranging from 430 pounds, constant speed, to 810 pounds at 4 to 1 range of speed. Curve C is for a three wire motor, weight rang-

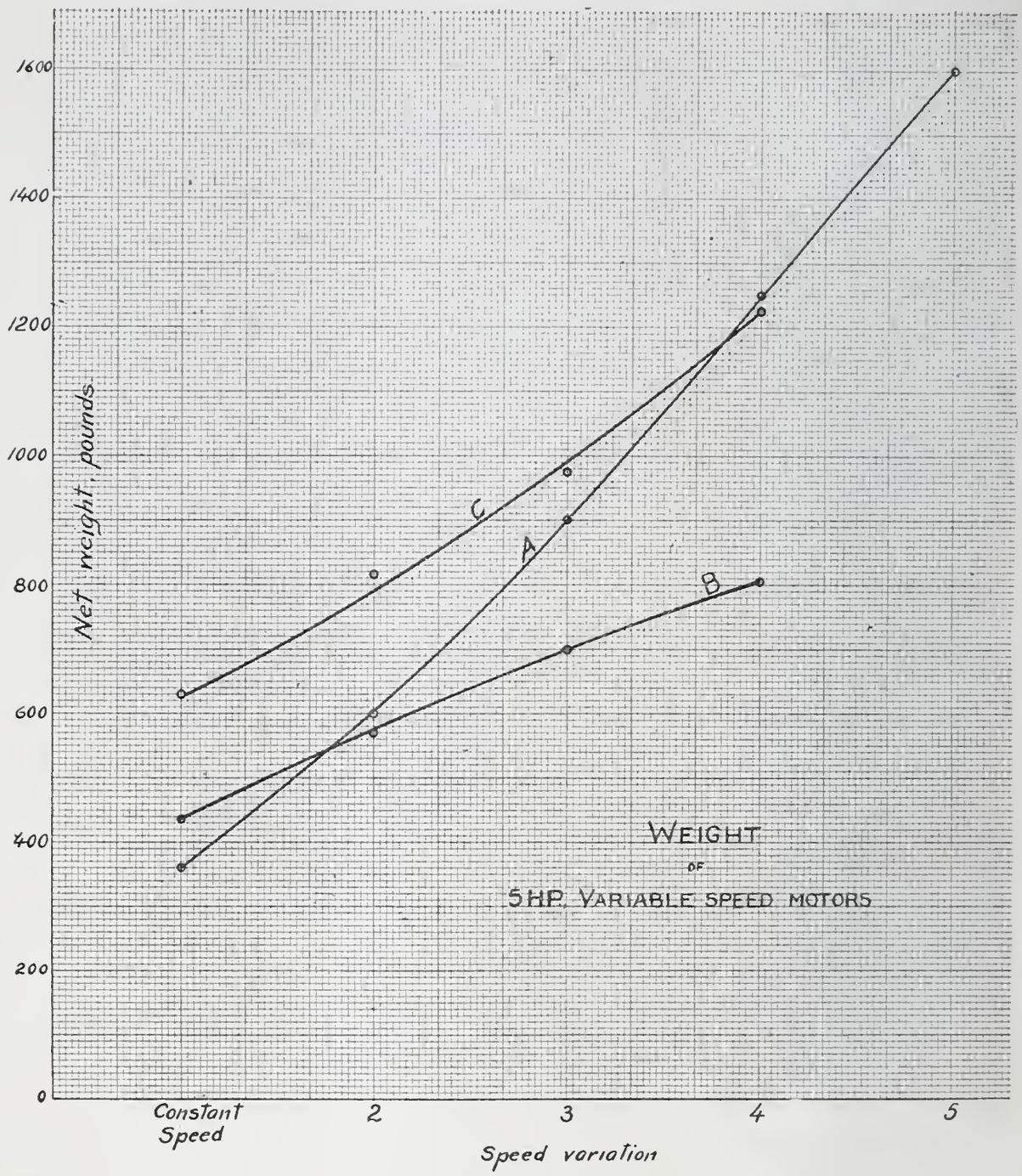

FIG. 2.

ing from 625 to 1225 pounds. These particular motors are taken simply as examples; the proportions given are special and not general, other types and makes of motors would give different motor curves. The writer does not guarantee the

correctness of the figures as published in the manufacturers' catalogues as extracted above.

From these examples it is quite evident that when it is stated a certain machine requires, for example, a 5 horse power motor, such a statement means very little unless the conditions under which the motor is operated or the particular basis on which the motor is rated is given.

Other conditions being the same, the power taken by a machine, after allowance is made for friction losses, will vary approximately as the speed and cut and therefore as the weight of metal removed, consequently in fitting motors to tools due allowance must be made for high speeds and maximum cuts, bearing in mind the coming universal use of high speed tool steels and the increase in rigidity of machines. A formula for the amount of power absorbed in cutting may be stated thus:

$$HP = K\,W$$

where HP = Horse power
K = A constant, depending on the kind and grade of material.
W = Weight of metal, pounds removed per minute.

Values of K may be taken as follows:

K = 2.5 for hard steel.
= 2.0 for wrought iron.
= 1.8 for soft steel.
= 1.4 for cast iron.

This formula is simply a general one, the power required in any particular case will vary perhaps 100% according to the condition of the cutting tool. To show how this formula applies, examples in tables below are given. These examples are taken at random from various machines tested and under ordinary conditions of shop working, they are not results of special tests. The machines, it will be noted, include several different types, some had one tool working, some two. The horse power actually taken for the cut was obtained by

deducting from the total power absorbed by the machine the power required to run the machine light at the same speed. This is not quite correct in some cases, for example, in drilling as will be shown later.

HARD STEEL.

Machine	Cut: Feed Inches	Cut: Depth Inches	Speed Ft. per Min.	Weight Removed Lbs. pr M.	H.P.: Actual	H.P.: From Formula
72″ Wheel Lathe No. 14	$\frac{1}{12}$	$\frac{3}{16}$ & $\frac{1}{4}$	13.7	1.69	4.5	4.2
"	$\frac{1}{8}$	$\frac{3}{16}$ & $\frac{1}{4}$	11.6	2.15	6.4	5.4
"	$\frac{3}{16}$	$\frac{5}{16}$ & $\frac{3}{8}$	13.2	5.55	8.4	13.9
"	$\frac{3}{16}$	$\frac{3}{8}$ & $\frac{3}{8}$	13.2	6.3	12.0	15.7
90″ Wheel Lathe No. 23	$\frac{3}{16}$	$\frac{3}{16}$ & $\frac{3}{16}$	13.0	3.1	12.0	7.7
"	$\frac{3}{16}$	$\frac{5}{16}$ & $\frac{5}{16}$	8.8	3.5	8.1	8.7
"	$\frac{1}{5}$	$\frac{5}{16}$ & $\frac{1}{4}$	10.5	4.0	7.3	10.0
"	$\frac{1}{5}$	$\frac{1}{4}$ & $\frac{1}{4}$	15.5	5.3	9.0	13.2
"	$\frac{1}{5}$	$\frac{3}{8}$ & $\frac{3}{8}$	12.3	6.3	13.4	15.7
19″ Slotter No. 77....	$\frac{1}{32}$	$\frac{1}{4}$	30.0	0.8	2.0	2.0
"	$\frac{1}{32}$	$\frac{1}{4}$	28.8	0.76	1.7	1.9
					84.8	98.4

SOFT STEEL.

Machine	Cut: Feed Inches	Cut: Depth Inches	Speed Ft. per Min.	Weight Removed Lbs. pr M.	H.P.: Actual	H.P.: From Formula
60″ Planer No. 52....	$\frac{1}{6}$	$\frac{1}{4}$	25.5	3.62	5.9	6.5
"	$\frac{1}{6}$	$\frac{1}{4}$	25.7	3.65	6.5	6.6
24″ Shaper No. 64.....	$\frac{1}{16}$	$\frac{3}{16}$	26.7	1.46	3.4	2.5
"	$\frac{1}{16}$	$\frac{1}{8}$	37.5	1.00	2.7	1.8
"	$\frac{1}{16}$	$\frac{1}{8}$	41.7	1.11	2.6	2.0
72″ Boring Mill No. 29	$\frac{1}{8}$	$\frac{1}{16}$ & $\frac{1}{32}$	44	1.76	2.9	3.2
"	$\frac{3}{16}$	$\frac{1}{32}$ & $\frac{1}{16}$	40	2.38	2.6	4.3
"	$\frac{1}{8}$	$\frac{1}{8}$ & $\frac{1}{8}$	51	5.41	9.6	9.7
"	$\frac{1}{8}$	$\frac{3}{16}$ & $\frac{3}{16}$	48	7.65	12.7	13.7
"	$\frac{1}{8}$	$\frac{3}{16}$	47	3.75	7.2	6.8
19″ Slotter No. 77.....	$\frac{1}{32}$	$\frac{3}{8}$	23.3	0.93	1.3	1.7
"	$\frac{1}{32}$	$\frac{3}{8}$	23.3	0.93	2.1	1.7
42″ Lathe No. 10.....	$\frac{1}{16}$	$\frac{1}{4}$	44	2.33	3.8	4.2
"	$\frac{1}{16}$	$\frac{1}{8}$	44	1.17	1.7	1.9
"	$\frac{1}{16}$	$\frac{1}{8}$	44	1.17	2.6	1.9

SOFT STEEL—Continued.

Machine	Cut: Feed Inches	Cut: Depth Inches	Speed Ft. per Min.	Weight Removed Lbs. pr M.	H.P.: Actual	H.P.: From Formula
24″ Lathe No. 19.....	1/32	3/8	49.5	1.98	3.7	3.6
Axle Lathe No. 21....	3/16	1/4	27	4.3	5.9	7.7
"	1/16	1/4	51	2.7	5.0	4.9
"	1/16	1/16 & 1/16	51	1.4	2.8	2.5
"	1/16 & 1/32	3/8 & 3/8	46	5.5	8.2	9.9
Car Wheel Lathe No. 22	3/16	3/8 & 1/2	12.5	6.9	12.7	12.4
"	3/16	3/8 & 3/8	12.6	6.0	9.9	10.8
"	1/4	1/4	19.7	4.2	15.1	7.6
Axle Lathe No. 13....	1/16	3/16 & 3/16	43	3.43	4.9	6.2
"	1/16	1/8 & 3/32	44	2.04	3.7	3.7
"	1/16	1/8 & 1/8	33	1.75	2.3	3.1
32″ Gisholt Lathe No. 70	1/32	1/4	84	2.2	4.3	4.0
"	1/32	3/16	94	1.9	3.6	3.4
"	1/64	5/16	64	1.1	1.6	2.0
					151.3	150.3

WROUGHT IRON.

24″ Drill Press No. 39.	1/64	enlarging 1 1/4 – 3	25.1	0.81	2.3	1.6
"	1/64	" 1 1/4 – 3	29.7	0.96	2.7	1.9
"	1/64	" 1 1/4 – 3	25.9	0.83	1.3	1.7
"	1/64	1 1/4″ Drill	74.5	0.52	3.5	1.0
"	1/64	2 ″ "	20.9	0.54	1.2	1.1
"	1/64	2 ″ "	20.9	0.54	2.2	1.1
24″ Drill Press No. 40.	1/32	enlarging 1/2 to 2″	20.9	1.02	1.4	2.0
"	1/64	1 5/8″ Drill	36.8	0.63	2.6	1.3
60″ Radial No. 147....	1/64	1 1/4″ "	53.9	0.88	2.7	1.8
"	1/64	1 1/4″ "	51.7	0.84	2.5	1.7
30″ Lathe No. 20.....	1/8	3/16	54	4.2	6.6	8.4
"	1/8	3/16	42	3.2	4.0	6.4
60″ Planer No. 52.....	3/16	5/16 & 5/16	23	8.95	21.0	17.9
"	1/2	1/32 & 1/32	17.5	1.82	2.7	3.6
"	1/8	1/8 & 1/16	22.2	1.72	6.5	3.4
42″ Planer No. 55....	5/32	3/8	24.3	4.73	12.1	9.5
"	5/32	3/8	25	4.87	12.3	9.8
"	1/8	3/8	36	5.7	7.8	11.4
					95.4	85.6

CAST IRON.

Machine	Cut: Feed Inches	Cut: Depth Inches	Speed Ft. per Min.	Weight Removed Lbs. pr M.	H.P.: Actual	H.P.: From Formula
60″ Planer No. 52.....	1/8 & 1/16	1/4 & 5/16	30	4.74	9.3	6.6
"	1/7	1/4 & 1/4	22.6	5.03	7.6	7.1
"	1/4	7/16 & 3/8	28.9	18.3	23.2	25.6
42″ Planer No. 55.....	3/16	3/16	37	4.06	4.7	5.7
"	3/64	1/8	37	2.71	4.1	3.8
"	3/16	1/16	40	1.46	2.6	2.1
72″ Boring Mill o. 29	1/16	3/8	28	2.05	2.6	2.9
"	1/12	1/8	33	1.07	1.4	1.5
"	1/16	1/4	39	1.90	2.7	2.7
42″ Lathe No. 10.....	1/16	1/8	108	2.63	5.8	3.7
"	1/16	3/16	46	1.74	2.9	2.5
"	1/16	3/16	58	2.12	2.2	3.0
"	1/16	3/16	45	1.64	1.9	2.3
30″ Lathe No. 20.....	3/32	5/32	42	1.92	3.0	2.7
"	3/32	1/16	61	1.12	1.5	1.6
"	1/64	1/4	47	2.30	2.0	3.2
"	1/32	1/4	55	1.34	2.0	1.9
					77.5	78.9

There is considerable discrepancy in some of the figures, this is as might be expected, but in general the agreement is sufficiently close to show that the formula is a reasonable one for arriving at the approximate horse power required for doing the actual work. The readings for hard steel are rather erratic, this is quite natural as the grade of steel in wheels varies widely; some of the material in that class should evidently be in the soft steel class. The figures for the drill presses are also rather divergent, this is especially the case in drilling but not so much so in enlarging. The main reason for this is the inaccuracy of the light load losses. The friction loss of the machine running idle is not the same as the friction loss when the machine is working. This friction loss should have been obtained by putting in a non cutting drill and applying the pressure. In connection with the tables, it may be noted also that the readings for wrought iron are too few to be of any value.

Another factor which enters into the capacity of the motor required is the friction loss of the machine itself, this is a factor impossible to predetermine but fortunately is not very large except on very large machines; it depends greatly on the gear reduction. A few examples of friction losses

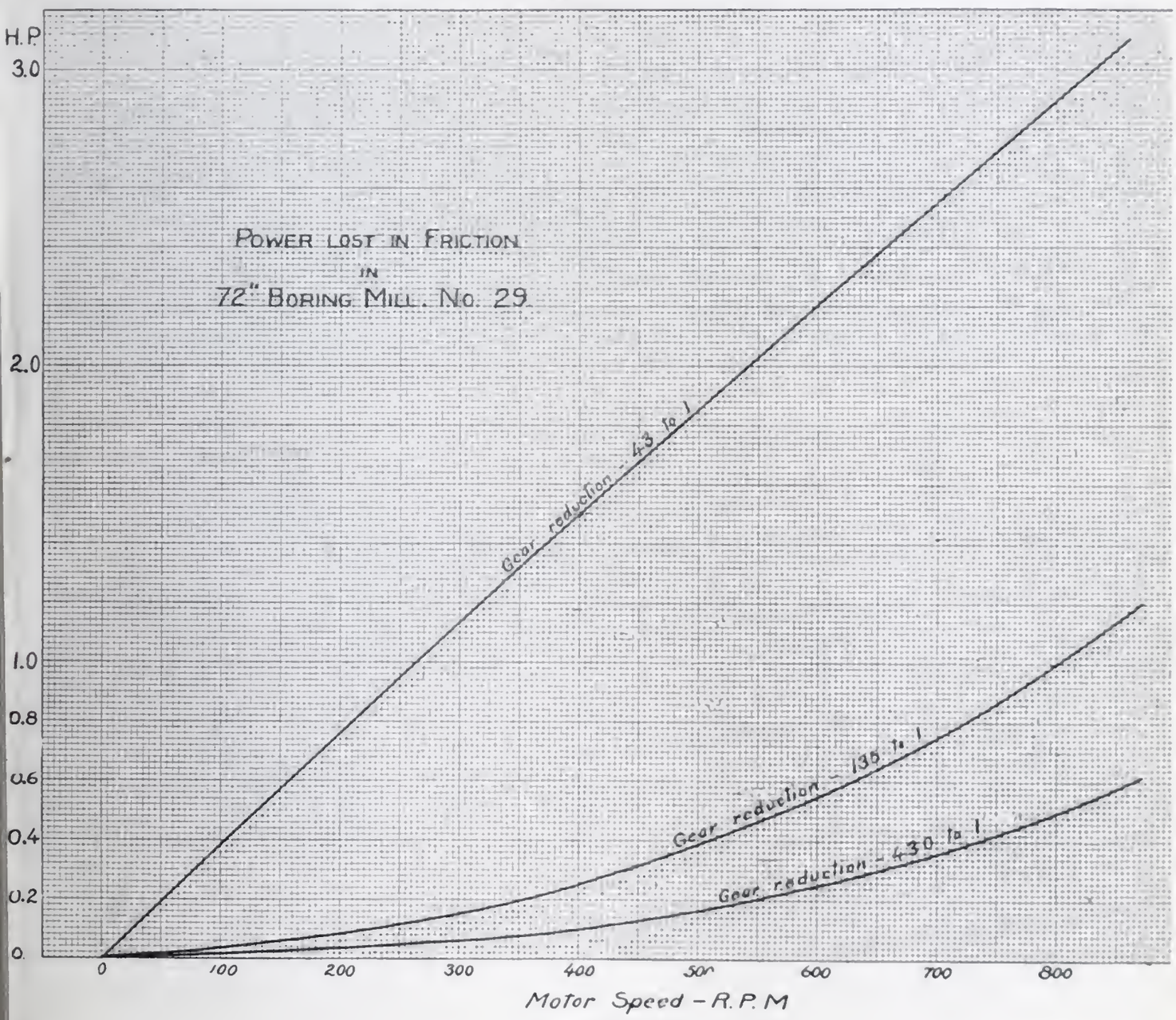

Fig. 3.

will serve to show the general run of such losses; the power lost in other machines may be assumed by comparison.

Figure 3 shows the power lost in friction in P. & L. E. tool No. 29, a 72 inch Pond boring mill. There is a difference in lost power in the different gear ratios ranging from 2.9

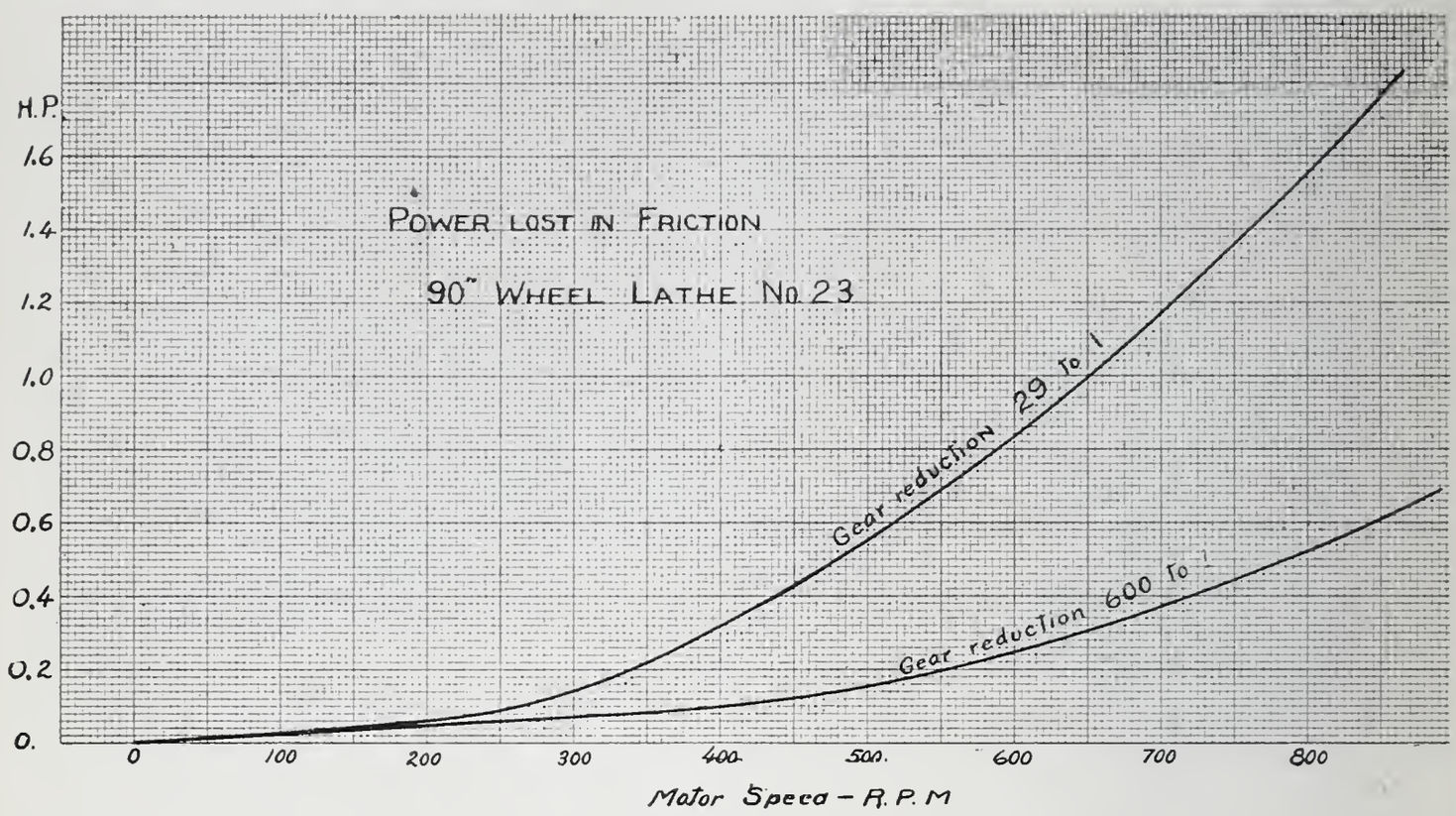
H.P.
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.
POWER LOST IN FRICTION
90" WHEEL LATHE No. 23
Gear reduction 29 to 1
Gear reduction 600 to 1
0
100
200
300
400
500
600
700
800
Motor Speed – R.P.M

FIG. 4.

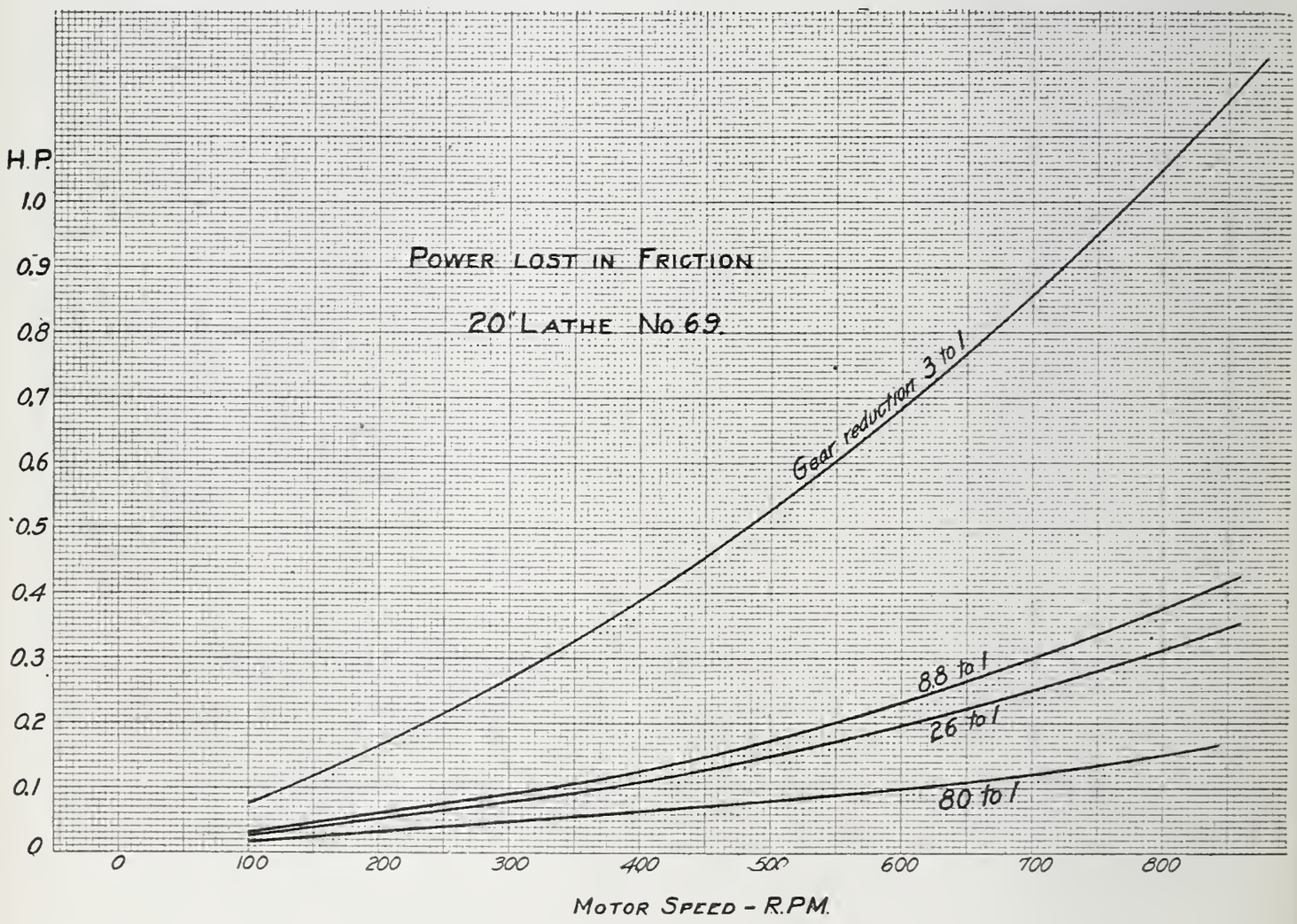
H.P.
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
POWER LOST IN FRICTION
20" LATHE No. 69
Gear reduction 3 to 1
8.8 to 1
26 to 1
80 to 1
0
100
200
300
400
500
600
700
800
MOTOR SPEED – R.P.M.

FIG. 5.

horse power for the high speed spindle to 0.5 horse power for the low speed spindle with motor running at the same speed, 800 revolutions per minute. The spindle speeds for a loss of 0.5 horse power are 3.14, 4.22 and 1.86, respectively, showing that the loss in friction is not directly proportional either to motor speed or spindle speed. This holds true for all tools.

Figure 4 is for tool No. 23, a 90 inch Putnam driving wheel lathe. This is quite a large machine, but the friction loss is small, only 1.6 horse power maximum for high spindle speed and 0.55 horse power for low spindle speed. Although the gear reductions vary considerably, 29 to 1 and 600 to 1, yet the total actual difference in lost power is not very large.

Figure 5 is for a 20 inch by 11 foot Putnam lathe, gear reduction varying from 3-1 to 80-1. The maximum loss is about 1.2 horse power.

Fig. 6 shows incidentally the power lost in a 60 inch planer, Figs. 8 and 9, in punches; Figs. 15, 16 and 17, in some wood working tools.

Similar curves could be given for a large number of machines but these are sufficient to show the general trend of the losses, especially as they show that the losses are small, except when the spindle or table is running at top speed. At the high spindle speed it is rather unlikely that a maximum cut is to be taken but in all probability only light finishing cuts or polishing, so that in general the power lost in friction in the machine, may be neglected in considering the question of size of motor required.

There is a class of machines where the size of motor required depends very largely on the machine itself, almost independent of the size of cut it has to take, this is the reciprocating tool, as the shaper and planer and to a somewhat less extent the intermittent working machines, such as punches and shears. In planers where shifting of belts is relied on to reverse the motion, the statement is fairly accurate; in tools where the reversal takes place by magnetic clutches or motor reversal it is not so much so, as the power taken by the motor

can be better regulated. In planer drives where motor runs continuously in one direction, it is of relatively little importance how much the platen or the load on it weighs, but the size and weight of the revolving pulleys which have to reverse it is of very great importance. These pulleys should be as small

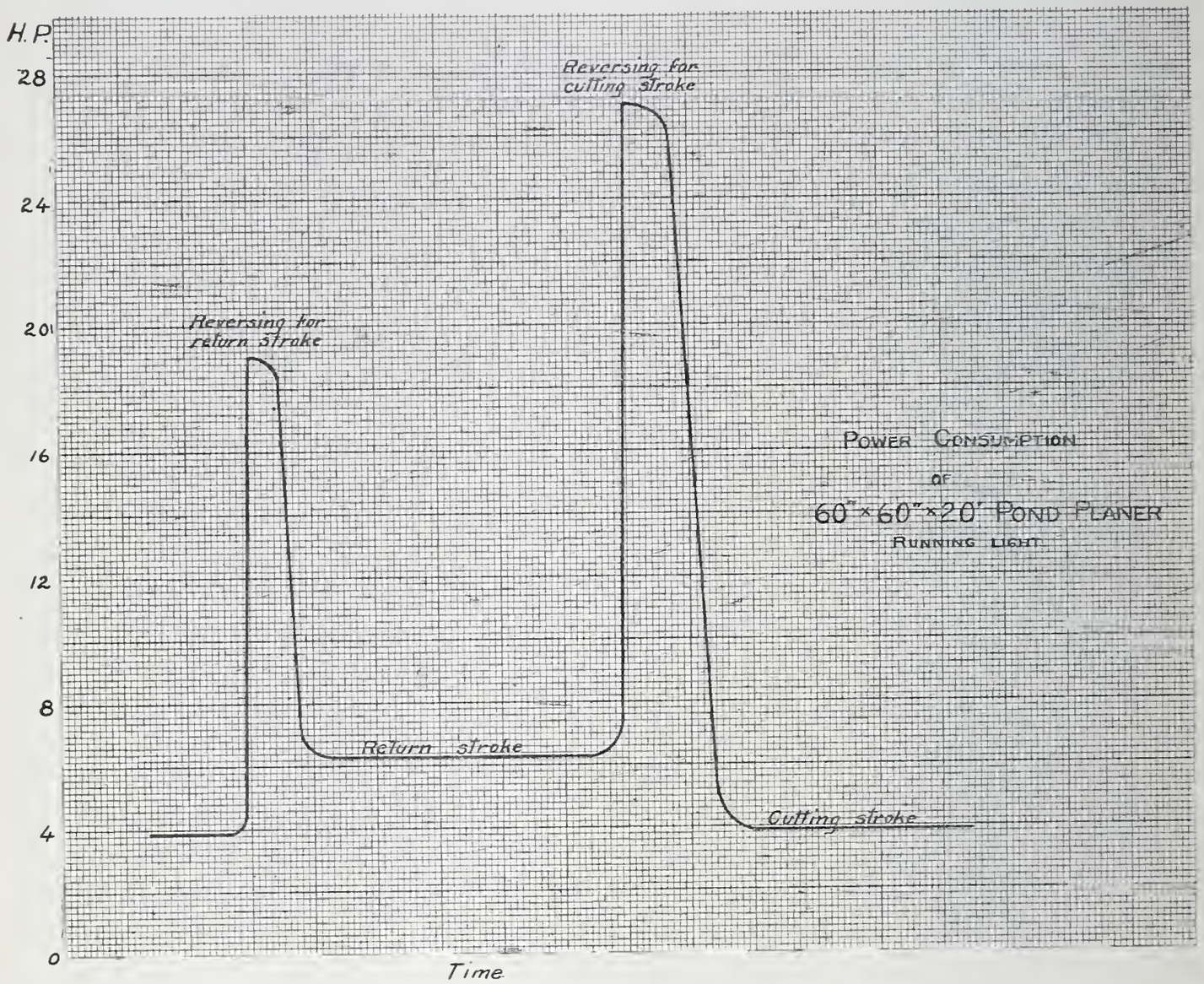

Fig. 6.

and light at the rim as capacity will allow; and on one of the revolving shafts, preferably on the motor shaft, there should be a fly wheel of large diameter and heavy rim so as to aid the motor at moment of reversal.

Fig. 6 is for machine No. 52, a 60 inch by 60 inch by 20 ft. Pond planer. The cycle of power consumption is rather remarkable but is a fair example of tools of this class

and method of drive, reversal by shifting belts. These readings were taken with the machine running light. During cutting stroke the horse power taken was 3.9, reversing to return stroke the power jumped to 19; on the return stroke it was 6.3 and in reversing to cutting stroke it rose to 27.0. Speed of the table in cutting stroke about 25 feet per

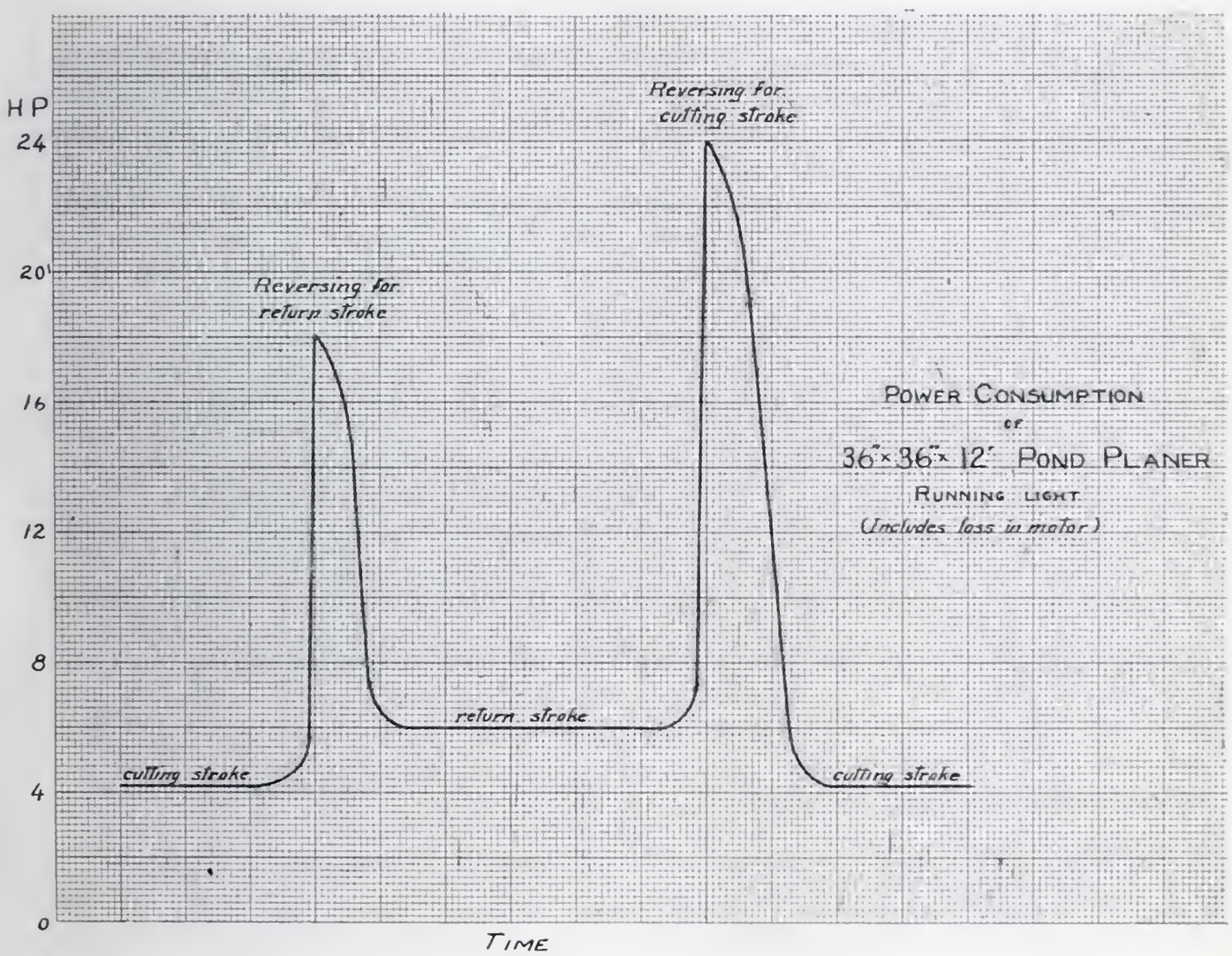

FIG. 7.

minute; on the reverse stroke, 60 feet per minute. This planer was driven by a compound wound Crocker-Wheeler motor 73.5 amperes, 20 horse power at full speed and voltage rating. The fly wheel on this machine is much too small but, owing to special design of the driving mechanism, it could not be increased. The driving mechanism would have to be improved considerably to make it suitable for much higher speeds.

Fig. 7 is of some tests on a 36 inch by 36 inch by 12 foot Pond planer on exhibition at St. Louis Exposition. This machine was driven by a reversing motor, belts being entirely done away with. The same general cycle is evident. Horse power, 4.1, to 18.0, to 6.0, to 24.0 and back to 4.1. Speed of table cutting stroke was 32 feet per minute, return stroke 75 feet per minute. The horse power in this curve includes the

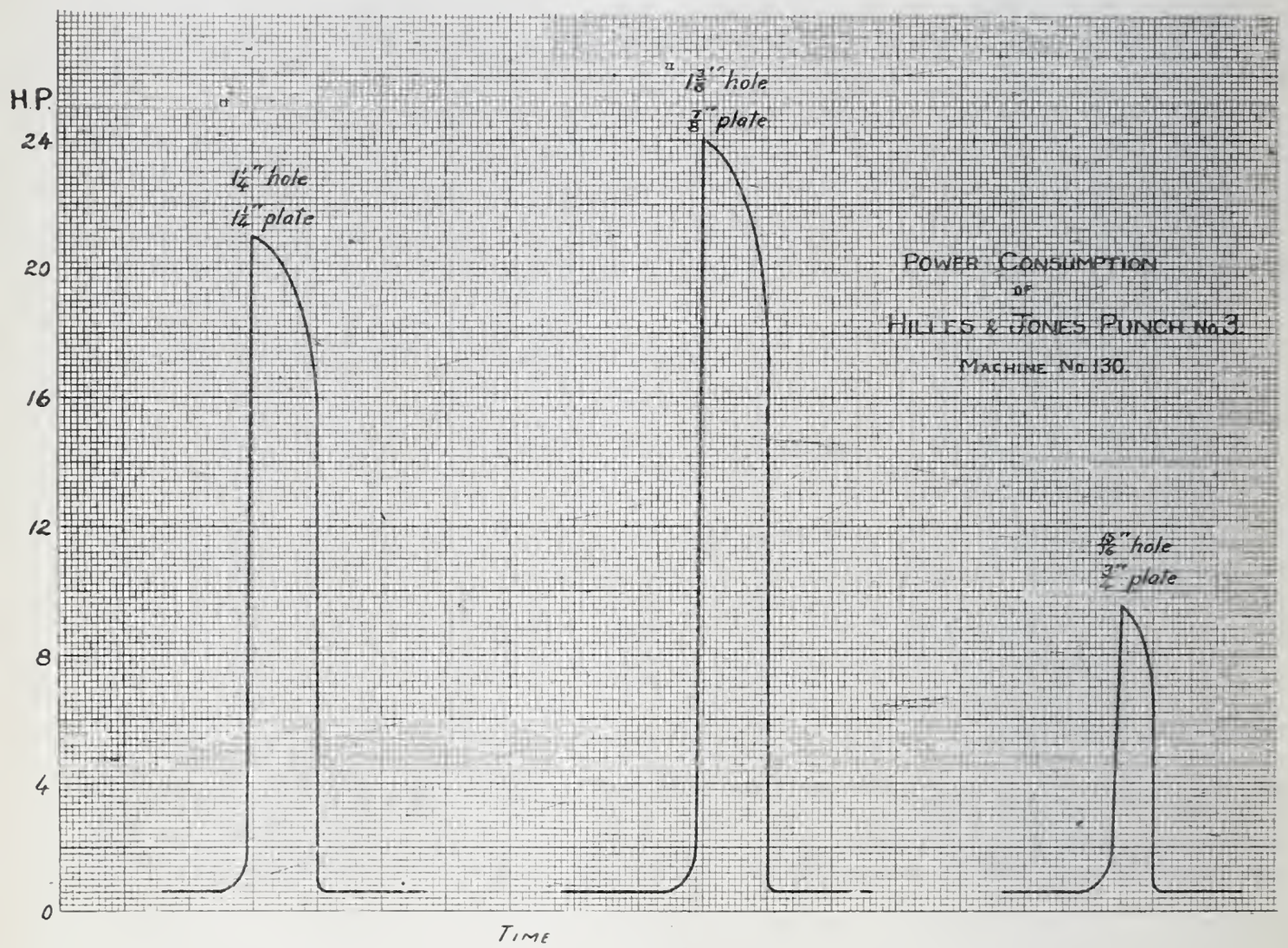

Fig. 8.

power losses in the motor itself which are not included in any of the other cuts. This planer was driven by a No. 7 6 horse power, type S, Westinghouse motor, speed change 4 to 1, rating 48 amperes at 110 or 220 volts. Loads obtained in taking heavy cuts were considerably in excess of the rating of the motor. In comparing the horse power rating of the motors on these two planers, the relative ratings given in

Fig. 1 must be borne in mind; they are not rated on the same basis.

Influence of design on the power required for punches and shears is well brought out by Figs. 8 and 9, each machine was used, for example, for punching a 1¼ inch hole in a 1¼ inch plate. In the lighter machine, No. 130, Fig. 8, the horse power rose to 21, while in No. 167, Fig. 9, only to 7.9, showing very clearly the influence of the heavy fly wheel and gear in the latter machine

In the shops of the P. & L. E. R. R. Co., at McKees Rocks, there are about 80 machines driven by individual

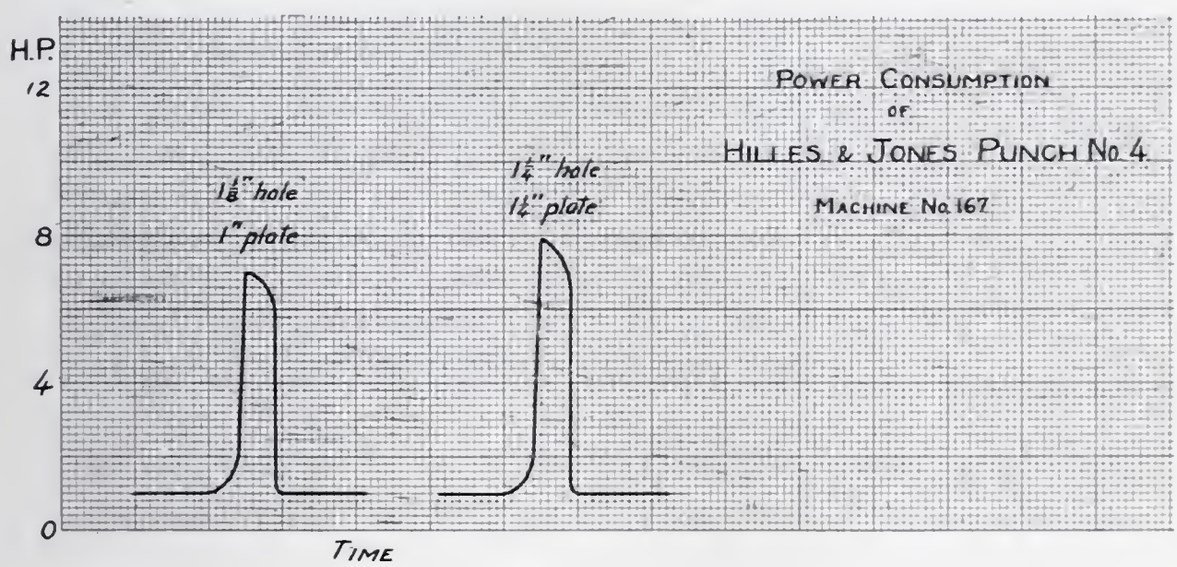

FIG. 9.

motors. For variable speed work, the speed variation required in the motor was, in general, about 2.8 to 1 for full power, but up to from 6 and 7½ to 1 for diminished power at low speeds, and the size of motor was approximately double the horse power required by the machine throughout this full power range, i. e., if the motor was rated as a variable speed motor, it would have a rating approximately one half that of the constant speed rating. The speed variation in many instances differed considerably from the above. In many of the drills, the speed variation was higher and in planers, shapers, etc., lower. As has been brought out in previous papers read before this Society, the speed control in these

shops is obtained by means of the multivoltage system. The horse power required by the machine was determined partly by general considerations and partly by the formula stated above, H P = K W, where K had a value of 3.6 for hard steels and 2.5 for soft steels. From data given on previous pages, it may be seen that the size of this constant was on the safe side. All machines are protected by both circuit breaker and fuses, the size of the breaker was, in general, 4 amperes per rated horse power of the motor and it was set at the limit of 50% above this rating, the breaker would therefore fly out

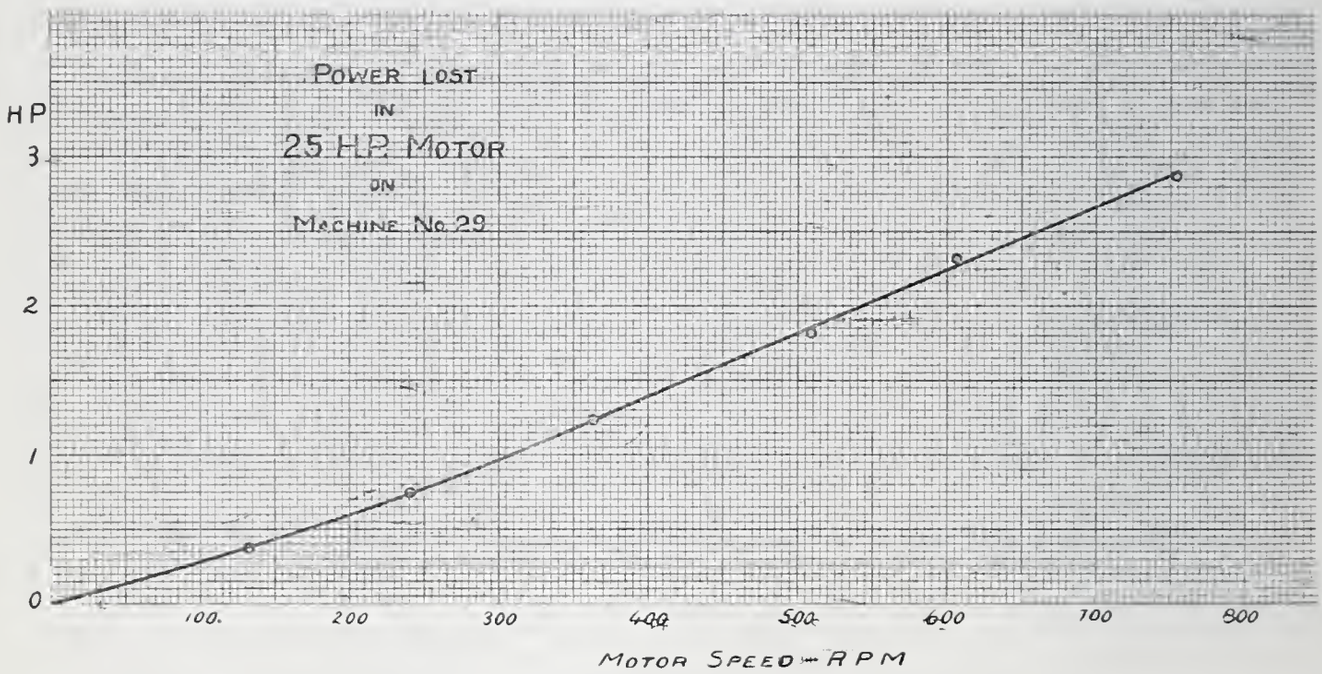

FIG. 11,

when the power consumption was approximately 100% overload. On reciprocating tools, the circuit breaker was set 40 to 50% higher. The enclosed fuses used had a rating the same as that at which the circuit breakers were set.

The individual motor driven tools used in these shops and the size of motors are given in the tool list below. When the horse power differs from the size of motor, it indicates that the motor is a high speed one. CM stands for shunt motor, CCM for compound. The letters I, F, and D after the initial number indicate type of frame. The number indicates the size and in every case is the same as the horse power of

the motor run at low speed, 230 volts. Motors marked with an asterisk (*) are constant speed, all others are used as variable speed motors. All motors are the standard motors of the Crocker-Wheeler Co., and the ratings are for constant speed at 240 volts.

TOOL LIST.

Tool	Description	Builder	Motor
5	18″ by 8′ Lathe	Flather & Co.	5 I, 5 H. P. CM
6	20″ by 8′ "	F. E. Reed Co.	5 I, 5 H. P. CM
7	20″ by 8′ "	F. E. Reed Co.	5 I, 5 H. P. CM
8	25″ by 6′ "	Putnam Machine Co.	7½ I, 7½ H. P. CM
10	42″ by 8′ "	Niles Tool Works Co.	15 I, 15 H. P. CM
11	24″ by 12′ "	American Tool Works Co.	7½ I, 7½ H. P. CM
13	Axle Lathe	Pond Machine Tool Co.	25 I, 25 H. P. CM
14	72″ Wheel Lathe	Niles Tool Works Co.	25 I, 25 H. P. CM
16	Turret Lathe	Jones & Lamison Mach. Co.	5 I, 5 H. P. CM
16½	" "	Jones & Lamson Mach Co.	5 I, 5 H. P. CM
17	" "	American Tool & Mach. Co.	3 I, 3 H. P. CM
18	" "	American Tool & Mach. Co.	5 I, 5 H. P. CM
—	" "	Warner & Swasey Co.	5 I, 5 H. P. CM
19	24″ by 12′ Lathe	American Tool Works Co.	7½ I, 7½ H. P. CM
20	30″ by 15′ "	Putnam Machine Co.	10 I, 10 H. P. CM
21	Axle Lathe	Putnam Machine Co.	35 I, 35 H. P. CM
22	42″ Car Wheel Lathe	Pond Machine Tool Co.	20 I, 20 H. P. CM
23	90″ Wheel Lathe	Putnam Machine Co.	25 I, 25 H. P. CM
24	18″ by 10′ "	Putnam Machine Co.	7½ I, 7½ H. P. CM
25	36″ by 24′ "	Putnam Machine Co.	10 I, 10 H. P. CM
27	Hyd. Wheel Press, 200 ton	Niles Tool Works Co.	*7½ I, 7½ H. P. CCM
28	42″ Car Wheel Borer	Pond Machine Tool Co.	10 I, 10 H. P. CM
29	72″ Boring Mill	Pond Machine Tool Co.	25 I, 25 H. P. CM
30	100″ Hyd. Wheel Press	Putnam Machine Co.	*7½ I, 7½ H. P. CCM
31	18″ by 36″ Horizontal Boring Machine	Betts Machine Co.	15 I, 15 H. P. CM
32	84″ Quartering Mach.	Niles Tool Works Co.	(2) 5 I, 5 H. P. CM
33	51″ Boring Mill	Bausch Machine Tool Co.	15 I, 15 H. P. CM
37	36″ Drill Press		3 F, 4 H. P. CM
38, 39 40 & 41, same as No. 37			
43	72″ Radial Drill	Niles Tool Works Co.	3 F, 4 H. P. CM

TOOL LIST—Continued.

Tool	Description	Builder	Motor
46	Heavy Two Spindle Drill	Bement, Niles & Co.	(2) 7½ I, 9 H. P. CM
47	30″ Drill Press	J. E. Snyder	5 I, 5 H. P. CM
51	30″ by 30″ by 8′ Planer	New Haven Mfg. Co.	7½ I, 7½ H. P. CCM
52	60″ by 60″ by 20′ "	Pond Machine Tool Co.	20 I, 20 H. P. CCM
53	30″ by 30″ by 8′ "	Powell Planer Co.	7½ I, 7½ H. P. CCM
54	42″ by 42″ by 12′ "	Pond Machine Tool Co.	15 I, 15 H. P. CCM
55	42″ by 42″ by 12′ "	Cincinnati Planer Co.	15 I, 15 H. P. CCM
62	12″ Shaper	Huvhes & Phillips	5 I, 5 H. P. CCM
63	24″ "	Gould & Eberhardt	7½ I, 7½ H. P. CCM
64	24″ Traversing Head Shaper	Cincinnati Shaper Co.	7½ I, 7½ H. P. CCM
67	20″ by 11′ Lathe	Putnam Machine Co.	7½ I, 7½ H. P. CM
68	20″ by 11′ "	Putnam Machine Co.	7½ I, 7½ H. P. CM
69	20″ by 11′ "	Putnam Machine Co.	7½ I, 7½ H. P. CM
70	34″ Gisholt Turret Lathe	Gisholt Machine Co.	15 I, 15 H. P. CM
71	Slab Miller	Wm. Sellers & Co.	5 I, 6¼ H. P. CCM
76	12″ Slotter	Betts Machine Co.	5 I, 6¼ H. P. CCM
77	19″ "	Putnam Machine Co.	10 I, 13 H. P. CCM
91	6″ Pipe Cutter	D. Saunders' Sons	7½ I, 7½ H. P. CM
92	3″ " "	D. Saunders' Sons	3 I, 3 H. P. CM
—	(3) 18″ Emery Wheel Grinders	Bridgeport Emery Whl. Co.	3 D, 4 H. P. CM
125	Bending Rolls No. 2	Hilles & Jones Co.	7½ I, 7½ H. P. CCM
126	Bending Rolls No. 4	Hilles & Jones Co.	25 I, 25 H. P. CCM
127	Straightening Rolls No 2	Hilles & Jones Co.	15 I, 15 H. P. CCM
130	Punch & Shear No. 3	Hilles & Jones Co.	*10 I, 10 H. P. CCM
131	Punch No. 2, with Spacing Table	Hilles & Jones Co.	10 I, 10 H. P. CCM
135	Punch 13-16″ Hole, 3-8″ Plate	Cleveland Punch and Shear Works Co.	*5 I, 5 H. P. CCM
136	Punch No. 5	Hilles & Jones Co.	*15 I, 15 H. P. CCM
137	Horizontal Punch	Hilles & Jones Co.	*10 I, 10 H. P. CCM
140	Shear No. 6	Hilles & Jones Co.	*15 I, 15 H. P. CCM
141	Angle Shear No. 1	Hilles & Jones Co.	*10 I, 10 H. P. CCM
147	60″ Radial Drill	Dresses Mach. Tool Co.	5 I, 6¼ H. P. CM
167	Punch & Shears No. 4	Hilles & Jones Co.	15 I, 15 H. P. CCM

In addition to these individual motor driven tools there are ten groups of tools in the several shops. In the wood working shops group driving in small groups is the rule. Group driving was used only where speed change was not required. There are at the plant about forty motors for other purposes than machine tool driving, also eleven electric cranes.

After the plant was in operation a large number of tests were made, every machine listed being tested to see whether or not the motor capacity was sufficient. In no case is the motor too small. In a few cases the motor could easily be reduced for P. & L. E. R. R. work; in general, the sizes are such as would be used providing the size of motors had to be fixed over again. Lathes Nos. 5, 6, 7, 16 and 16½ could be operated by a 3 horse power motor instead of 5, lathe No. 14 with a 5 horse power instead of 7½, but if the machine were used for heavier work than is supplied by these shops, the motors are none too large. Axle lathe No. 21 could at present do with a 15 or 20 horse power motor, instead of a 35, but the intention was to give sufficient capacity to allow axles to be received in the rough and to do all the rough turning; at present the axles are bought rough turned. Motor on punch and shears No. 130 is too small for punching larger than 1 inch hole in 1 inch plate but the machine should not be used for such work, although the manufacturers state it is good for punching 1½ inch hole in 1 inch plate; if so the fly wheel should be very considerably increased.

In making tests three separate sets were made;

1st, power required to drive the motor disconnected entirely from the machine, the motor being run at all the speeds.

2nd, power required to drive the machine on its different gear drives and different motor speeds.

3rd, the total power required during the time the machine gear drives and different motor speeds.

This latter set of tests was taken haphazard, i. e., the electrician simply passed from machine to machine and took readings and record of the cut, no attempt being made to get the record at the best tool efficiency, consequently the

72-INCH BORING MILL NO. 29.

Motor: Type C. M., 25 H. P. at 750 R. P. M., 230 V. 90.5 Amp.

R. P. M. of Table=2.35, 0.97 or 0.34% of Motor.

MOTOR					CUT			MATERIAL			REMARKS
Controller Point	Voltage	Current	R.P.M.	H. P. Input	Feed Inches	Depth Inches	Speed Ft. per Min.	Diam. Inches	Weight Pounds Min.	Kind	
18	240	4	.....	.....	.....	.....	.....	.....	.....	.....	Running light, table not turning
18	240	6	.....	.....	.....	.....	.....	.....	.....	.....	" " table turning
18	.....	20	785	.....	.125	.125 & .125	.....	19.5	.....	Cast Iron	Two heads
21	233	28	970	8.76	.....	.....	.....	.....	.....	.....	Running light
21	233	38	978	11.88	.0625	.094	47	7.5	0.99	Brass	
21	232	37	988	11.51	.0625	.0625	47	7.5	0.66	"	
4	76	38	243	3.77	.0625	.375	28	58	2.05	Cast Iron	
9	116	16	361	2.49	.....	.....	.....	.....	.....	.....	Running light
8	76	49	340	4.98	.0625	.25	39	58	1.90	Cast Iron	
12	115	33	480	5.08	.125	.062 & .031	44	44	1.24	Steel	
10	114	28	473	4.27	.125	.0625	42	44	1.11	"	
13	160	19	519	4.07	.....	.....	.....	.....	.....	.....	Running light
9	113	75	354	11.36	.125	.125 & .125	51	52	5.41	Steel	
9	112	95	349	14.26	.125	.187 & .187	48	52	7.65	"	
9	115	58	360	8.93	.125	.125 & .187	47	52	3.75	"	
17	195	25	684	6.54	.125	.125	80	19	4.50	Brass	
21	234	35	964	11.00	.125	.094 & .031	123	20	6.91	"	
20	235	30	915	9.47	.187	.031 & .016	115	20	3.64	"	
20	236	20	930	6.33	.....	.....	.....	.....	.....	.....	Running light
20	244	13	940	4.25	.083	.125	33	18	1.07	Cast Iron	
6	78	26	294	2.72	.083	.125	33	18	1.07	"	
15	161	15	612	3.24	.062	.062	24	20	1.29	"	

TABLE 10.

records give every day shop practice such as will probably be met with in the ordinary shop. Practically all the tests were made in 1904, not long after the new shops were running and consequently the cuts and speeds given are much lower than present day practice, nor was any attempt made to make tests when the machines were taking heavy cuts. These points must be borne in mind if cuts and feeds are examined.

After the tests were made, the first set would be compared motor to motor to see if all motors were equally efficient, then the first set would be subtracted from the second to obtain friction losses in the various machines and finally the second set would be subtracted from the third to find the actual horse power taken by the cutting tool or tools. The curves for the motors need not be reproduced, as the loss is on the input and not on output of the motor. The horse power of the motor being brake horse power, losses are allowed for by the manufacturers. The curve of power lost by friction is given for a few cases in Figs. 3, 4, 5, 6, 8, 9, 15, 16 and 17, and the power taken by the cut is given in the general summary near the beginning of this paper. As a sample, however, of the tests made, table 10 is given for the 72 inch boring mill, No. 29. The horse power given is the input into the motor, not the horse power of the cut. The horse power lost by friction given in Fig. 3 and the power lost in the motor given in Fig. 11., must be subtracted to get the actual tool power consumption. The horse power taken by the first two items, while working brass, is abnormal, the cutting tools must have had excessive negative rake, the two readings were evidently taken on the one job. The readings for cutting brass lower down the list are more like what would be expected.

Table 12 is of some of the readings taken on the 90 inch driving wheel lathe No. 23. After eliminating the power lost in friction given in Fig. 4 and in the motor, practically the same as in Fig. 11 the horse power required to remove one pound of metal is given in Fig. 13; the amount varies from

90-INCH DRIVING WHEEL LATHE No. 23.

Motor: Type C. M., 25 H. P., at 750 R. P. M., 230 V., 90.5 Amp.

R. P. M. of Spindle=3.63, or 0.167 % of Motor.

MOTOR					CUT			MATERIAL			REMARKS
Controller Point	Voltage	Current	R.P.M.	H. P. Input	Feed Inches	Depth Inches	Speed Ft. per Min,	Dia. Inches	Weight Pounds Min.	Kind	
16	188	60	637	15.1	3/16	3/16 & 3/16	13.0	48	3.1	Steel	Double Head
13	157	50	430	10 5	3/16	5/16 & 5/16	8.8	48	3 5	"	" "
16	190	70	650	17.8	3/16	1/4 & 1/4	13.3	48	4 2	"	" "
13	156	45	540	9.4	3/16	3/16 & 3/16	10.9	48	2.6	"	" "
13	156	75	537	15.7	1/5	3/8 & 3/8	12.3	54	6.3	"	" "
13	156	70	536	14 6	1/5	3/8 & 3/8	12.3	54	6 3	"	" "
9	113	80	355	12.1	1/5	5/16 & 1/4	10.5	69	4.0	"	" "
9	114	77	363	11.8	1/5	1/4 & 1/4	10,6	69	3.6	"	" "
11	115	60	450	9.1	1/5	3/16 & 1/4	13.4	71	4.0	"	" "
17	196	46	728	12.1	1/5	1/4 & 1/4	15.5	51	5.3	"	" "

TABLE 12.

3.87 to 1.70, certainly a very wide range but the grade of steel also varies widely.

As to the power required by wood working tools, the writer has formulated no general rules, a few sample power readings will be given to show the power required in certain machines. The power consumption in wood working tools is very large, very much larger than one might ordinarily expect. In adapting these machines for motor drive, the motor

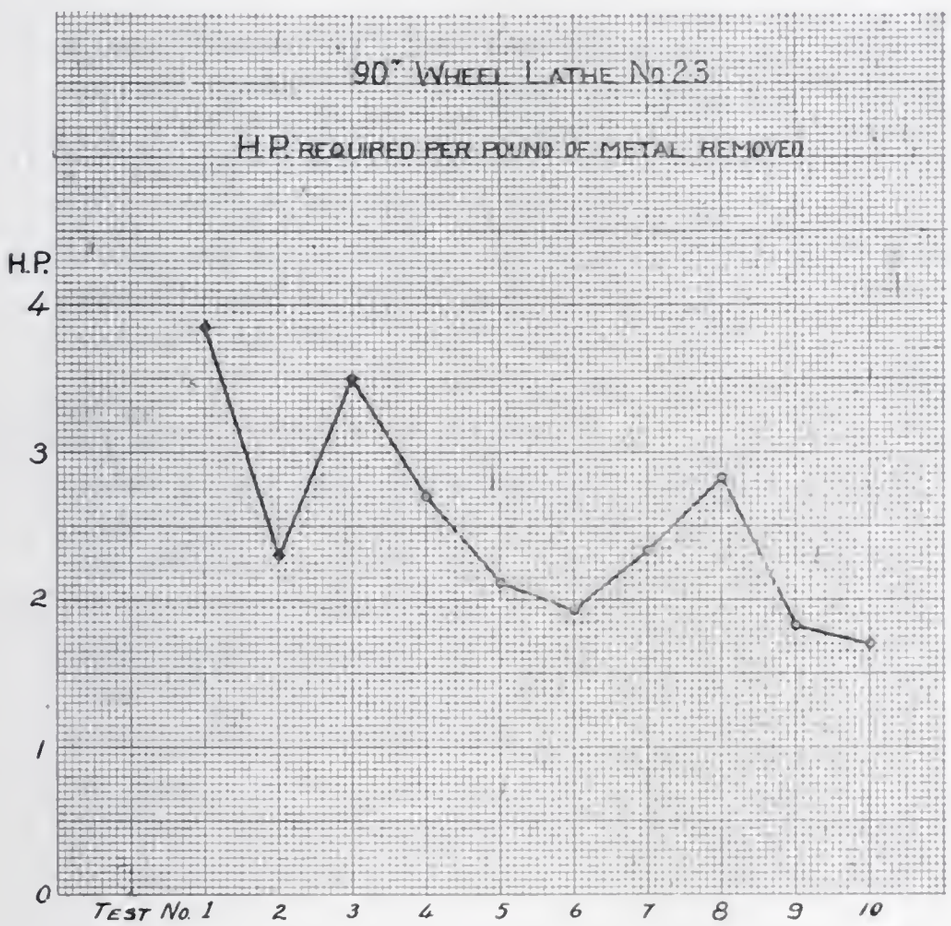

FIG. 13.

should have ample capacity when the machine is to be used continuously in a manufacturing shop.

Table 14 shows the power taken by an 18 inch by 30 inch Berlin planer.

Figure 15, gives the power required to drive an 8 inch by 24 inch Fay planer reducing a 6½ to 6¾ inch by 12 inch and a 6¾ to 7 inch by 12 inch oak beam to 6 inches by 12 inches. Power required starting machine was about 25 horse

18-INCH BY 30-INCH WOOD WORKING PLANER.

Motor: Type C. C. M. 60 H. P. at 830 R. P. M. 230 V. 216 Amp.

MOTOR				CUT					REMARKS
Voltage	Current	R. P. M.	Input H. P.	Width Inches	Depth Inches	Feed Ft. per Min.	No. of Heads	Kind of Wood	
244	60	892	19.6	.....	.....	.....	.....	.....	Planer running light
233	85	833	26.6	11	.25	50	2	Oak	
232	95	839	29.5	11	.25	50	2	"	
231	110	830	34.1	22	.25	50	2	"	Planing two
231	110	826	34.1	16	.25	50	2	"	" "
230	130	822	40.2	24	.25	49	2	"	" three
241	100	868	32.3	16	.25	52	2	"	
239	150	828	48.0	12 + 12	.75 & .25	50	2	"	Hand feed
238	160	834	51.0	12 + 12	1.25 & .25	50	2	.....	" "
240	140	840	45.0	10 + 10	1.75 & .25	50	2	.....	" "

TABLE 14.

power, running light, 5.7 horse power. The power under cut includes the power loss running light. Readings were taken about 15 seconds apart.

Figure 16 is for a 32 inch cross cut saw, sawing 8 inch by 12 inch oak beams.

Figure 17 is for 30 inch rip saw, first part taking cut 6 inches deep in dry oak, second part 8 inches deep in very wet oak.

The total power lost in the motors and lost in friction in the machines is considerable, even though in individual cases it is not very large. To investigate this point, among others, some experiments were made on a Sunday when the shops were idle. Forty-six machines were selected every one equipped with an individual motor capable of speed variation. The machines were as follows:

Machines		Horse Power Rating of Motors
17	Lathes	215
5	Milling Machines and Boring Mills	70
5	Planers	66
5	Slotters and Shapers	35
9	Drilling Machines	50
5	Punches, Shapers, Rolls, etc	61
46		497

First, full current strength was put on all the fields, then all the motors were run on the 40 volt circuit, then all on the 80 volt circuit, 120 volt, 160 volt, 200 volt and 240 volt in turn and finally lathes and drills were run on the high speed point, approximately 30% above normal 240 volt speed, power consumption being noted at all the different points. All machines driven by these motors were in motion but no work was being done, nor was feed mechanism in use. The results are tabulated in Fig. 18; planer platens were not operating except for points 3, 6, and 8. The curve giving losses in motor armatures was platted from readings on a number of motors disconnected

from machines. The speed of the motors varies approximately as the impressed voltage so it will be seen that after deducting 15.2 horse power for the fields the horse power lost in the motor armature and tool varies approximately as the speed. It will be noted that when all these forty-six tools were running at top speed, no useful work being done, the lost horse power was 105 pounds. The full losses given are never

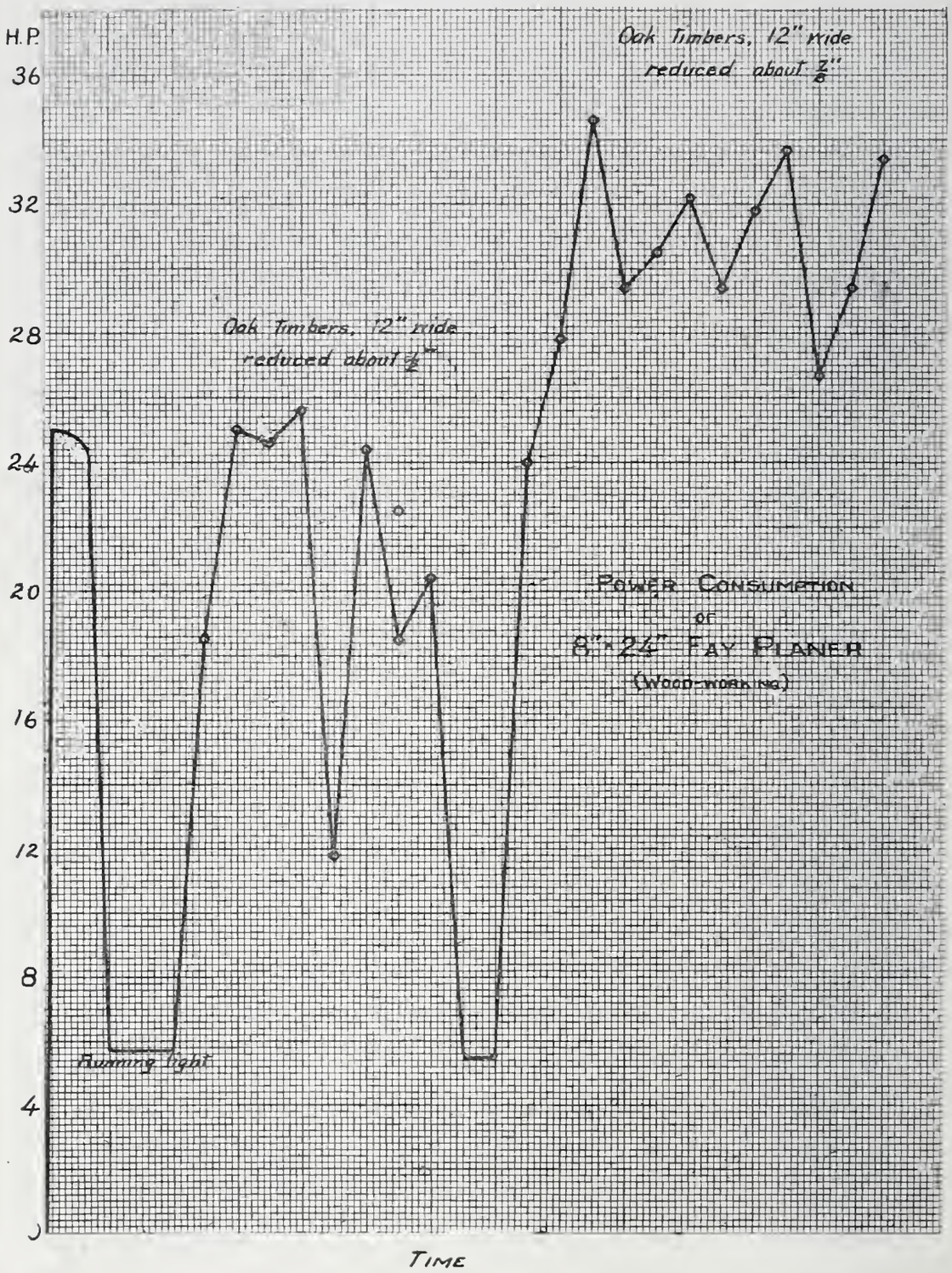

Fig. 15

incurred as the tools are never all running at one time and never all on the top motor speed, in fact the average or even the maximum power consumption on any working day when all the tools are working is less than the maximum for lost power alone. The part of curve at the right hand in the cut is the total power consumption for all the tools included above and a few constant speed motors besides. These readings were taken every two hours during the six working days succeeding the Sunday on which the readings for power losses were taken.

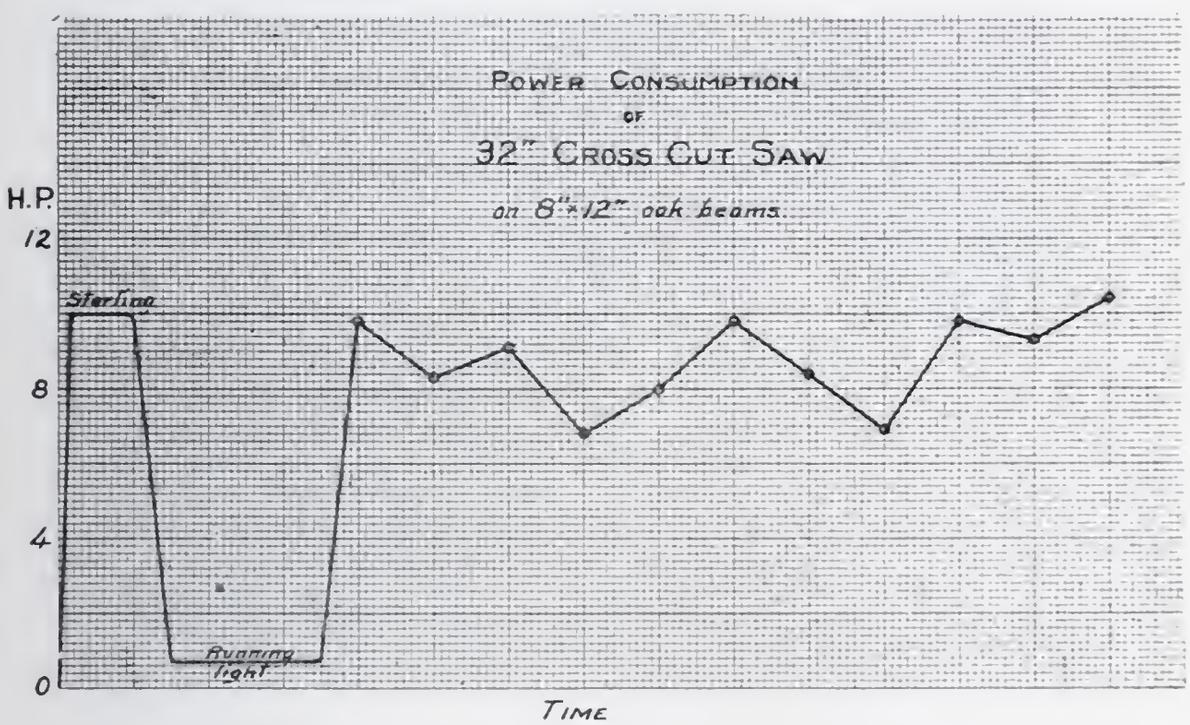

Fig. 16

A large number of special conditions may enter into the determination of the size of the motor required for any particular tool, the class of work it is to be restricted to, the grade of material, whether cuts, if heavy, will be of short duration etc., so that it is rather difficult to make a statement that will fit all cases, but the writer would suggest the following for determining size of motor for average conditions—assume a cutting speed of 50 to 70 feet a minute for soft steels, estimate the maximum size of cut that will likely be required for any time longer than 30 minutes, transfer this into pounds of metal removed per minute and multiply by 2.7(this figure

is 50% above the constant 1.8 used previously in this paper, the increase being for safety for bad conditions), then select a motor which will develop this power throughout the range of speed desired.

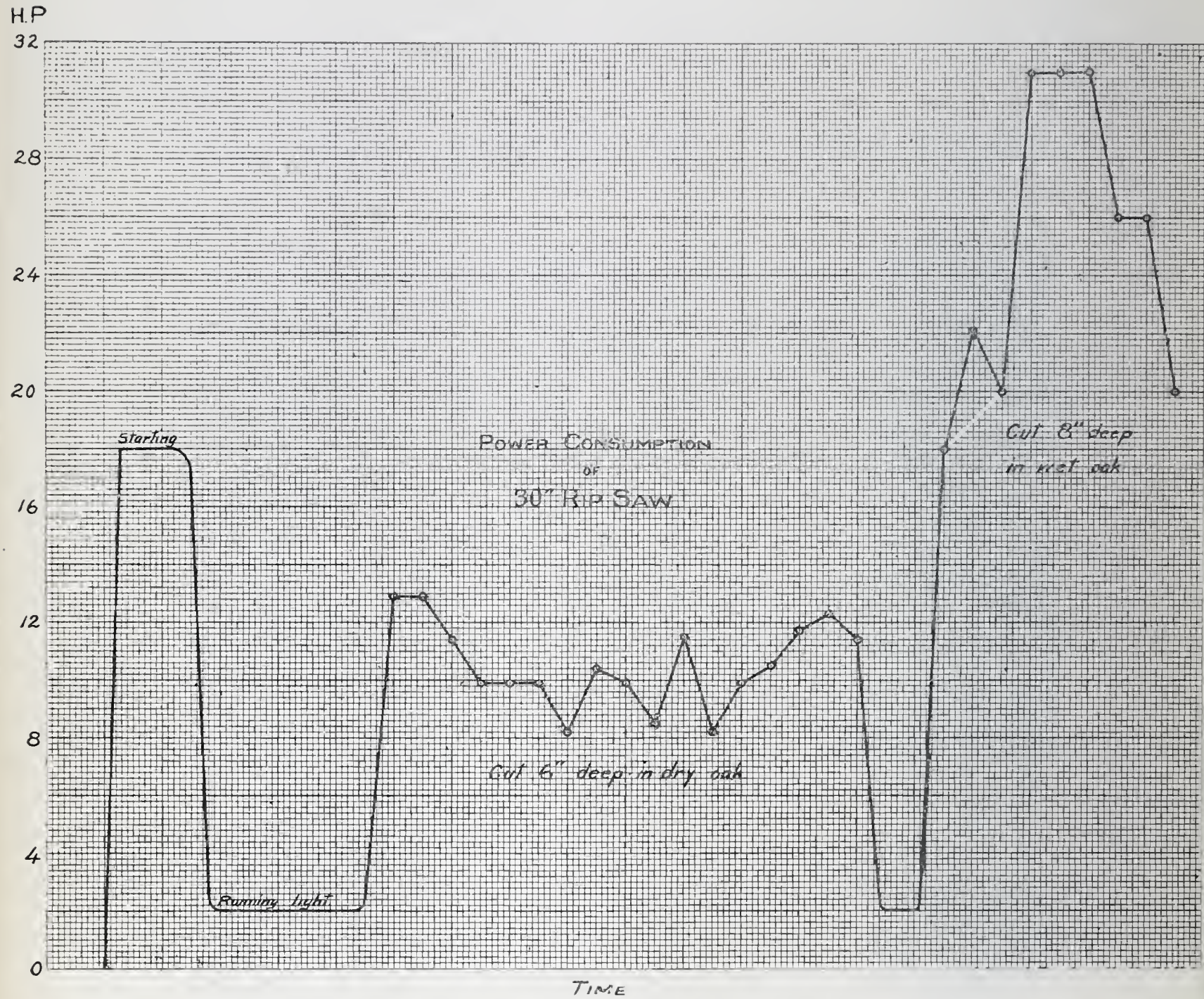

Fig. 17.

The record is not quite complete as it does not give the gear reductions in use, some of machines were using high speed, some low speed gears. If all the machines had been run on the highest speed gear the loss in friction in the machines would probably have been doubled.

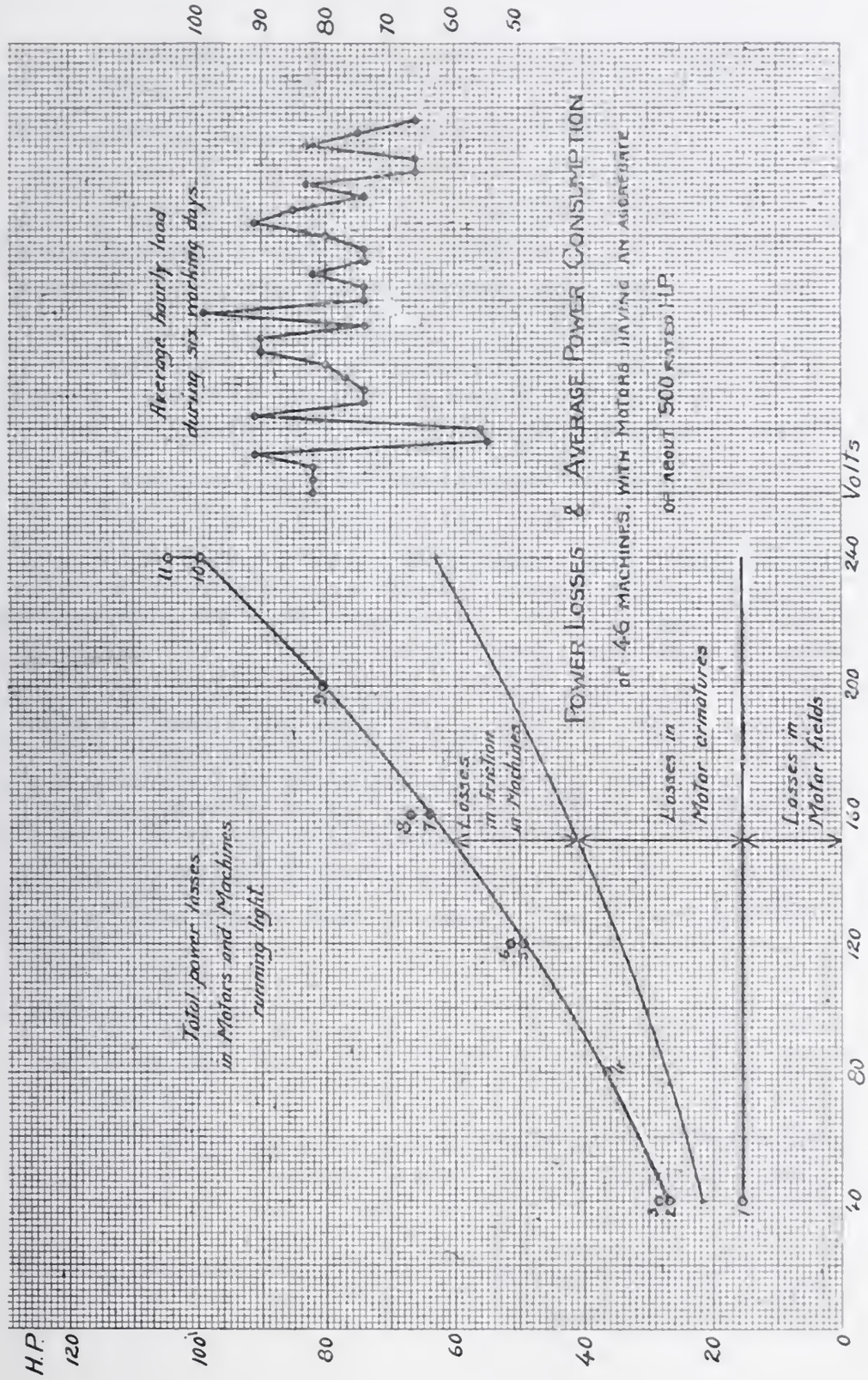
Power Losses & Average Power Consumption
of 46 Machines, with Motors having an aggregate
of about 500 rated H.P.
Average hourly load
during six working days
Total power losses
in Motors and Machines
running light
Losses
in Friction
in Machines
Losses in
Motor armatures
Losses in
Motor fields
H.P.
Volts
0
20
40
60
80
100
120
40
80
120
160
200
240
50
60
70
80
90
100

FIG. 18.

DISCUSSION.

A. A. LANE, Member—Has Mr. Campbell any data on the power required by cranes?

G. M. CAMPBELL—The ordinary power consumption for a crane lifting a 190,000 lb. locomotive in ordinary operation is about 90 horse power.

In this particular plant the total horse power rating of all motors other than cranes is about 1800, adding to that the crane motors bring it up to 2300 horse power. The actual rating in the power house at present is 900 horse power. If all this load were thrown on together it would swamp the power house, but, as shown in Figure 18, the total load for machine tools is less than the actual total friction loss in the machines, so you can see how small is the power required to operate tools. The power house equipment is too small, in view of several additional motors to be shortly installed, accordingly it will be increased before long.

E. H. HASLAM, Member—In regard to punching machines, Mr. Campbell fails to give the speed at which the punches were operating. He gives the speed at which the metal was being removed by lathes, planers, etc., but it does not appear in that case to make any difference, or affect the formula, whether the steel is being removed at the rate of 80 or 40 feet per minute.

G. M. CAMPBELL—I do not think it does make very much difference within certain limits, because there is a certain amount of lost motion in any punch. When the punch starts to work it comes up against the plate and then actually stops, on account of the lost motion in the machine, then goes through with a jerk.

E. H. HASLAM—To punch a plate at the rate of 60 strokes per minute will require more power than to do it at 20 strokes per minute.

G. M. CAMPBELL—It probably would, but not necessarily proportionately; it may take 25% more maybe not so much.

E. H. HASLAM—Has Mr. Campbell taken any readings

as to the amount of power required to start the various machines?

G. M. Campbell—We have quite a number of readings, but I do not have them with me. It ordinarily takes about the rating of the motor under ordinary speed to start.

F. E. McKee, Member—Have you found in your investigating that it was necessary to choose the size of motor on any particular shear, punch, or forging machine, simply for its starting load?

G. M. Campbell—On machines such as punches, shears, etc., where it is exceedingly hard to start, we provided a motor suited to the work. To take care of the starting friction clutches were put in, but as a matter of fact the men dislike so much to start with a friction clutch they never use them and actually start with the motor. That necessitated putting in a much heavier starting rheostat than is ordinarily provided with the motor, but the size of the motor was not increased.

W. H. Baltzell, Member—Do you know if any one uses automatic relay controllers of any kind on machine tools, such as planers and punches, similar to those used on blast furnace hoists, grab buckets or rolling mill reversing tables? I mean something of that type which allows only a predetermined amount of current to reach the motor in a given period and by prolonging the time of reversal prevents extreme rises in current.

G. M. Campbell—No, I do not. In general I think an ordinary controller is much better for tool work, but not for mill work. For machine tool work a hand operated controller is better than an automatic one, because the automatic requires a great deal of attention.

Some one has asked about the power to drive an emery wheel. With a double, 18 inch, emery wheel with a 4 horse power motor on the spindle, running at pretty high speed, we have no trouble whatever. We have a number of power readings and sometimes the load goes up to 7, 7½ or 8 horse power. This is only temporary. They are all for hand grind-

ing and a man to get 7 horse power out of the motor has to be a hard working man.

H. H. Anderson, Member—Has Mr. Campbell had any experience in grouping machines so as to determine whether there is any saving in the power required.

G. M. Campbell—As far as saving power is concerned there might be a saving by grouping the machines. That is not usually the assertion. The usual assertion is you save power by individual driving because you are using motors intermittently, but the total power loss is large in the motor itself, there is a continual loss in the coils. On group driving you can get along with a much smaller motor than the individual tools require, but the saving in power is not worth mentioning. It is not to be compared with the saving to be effected by increased output from the machines with an individual motor.

*URBAN BRIDGES

†WILLIS WHITED.

It is proposed in this paper to discuss briefly a few points in connection with the design and construction of urban bridges, as distinguished, on the one hand, from railroad bridges, and on the other hand from ordinary highway bridges. They differ from the latter in the much heavier traffic to be carried, necessitating ordinarily, paved roadways, ample sidewalks, and on account of the fact that they are frequently heavily loaded, smaller unit stresses. They also frequently involve complicated questions regarding the rights of abutting property owners, of corporations owning pipes, wires, etc., street railway corporations and steam railroad companies. They sometimes require the diversion of sewers, water mains and other structures, and must usually be erected in places where the space available for falsework, plant and storage of materials is very limited.

Every city should employ a competent engineer to design its new bridges and superintend the inspection of, and repairs to, its old ones, as the number of lives placed in jeopardy by an unsafe structure is very large, and bridges sometimes give way from deterioration, or from defects in design or construction, which would escape the notice of any but a trained engineer. Moreover, accidents sometimes happen to bridges, on important thoroughfares, which require the skill and judgment of the expert engineer to re-establish traffic as soon as possible, and, at the same time, to thoroughly protect the lives of the public. It is also good economy to employ experts to superintend the execution of bridge contracts and protect the interests of the public against the fraud and incom-

* Meeting Structural Section, December 26, 1905.

† Department Public Works, Pittsburgh, Pa.

petence of the contractors. Not that all, or nearly all, contractors are dishonest or incompetent, but if it is known that the city does not employ a competent man, the dishonest contractors are likely to bid low and get the work.

It is advisable for the engineer to prepare plans of the structure so complete that the bidders know exactly what they are expected to do, and, at the same time, give them a reasonable latitude in the use of their own shop methods and standards, and also to adapt them to any special method of erection that the contractor may find advantageous, the latter subject, of course, to the engineer's approval. It is usually impossible to determine beforehand the exact depth to which foundations must be carried. The engineer should ascertain as accurately as possible the location of all pipes, sewers, etc., which may interfere with foundations and make proper provision for them in his plans and specifications.

The specifications should be clear and concise and contain as little information as possible that is furnished by the plans. They should be free from all "club clauses" and unnecessary restrictions. They should state as accurately as possible what is expected of a contractor, as to quality of workmanship and material, and should contain no provisions which the engineer does not intend to strictly carry out. It is not good policy to describe anything in the specifications that can be shown on the plans, because the two methods of showing them will not always agree, thus causing confusion and disputes. "Club clauses," unnecessary conditions and restrictions are expensive, because the contractor is apt to make his price so as to protect himself in case they are strictly carried out. For the same reason, excessively severe specifictions are apt to be expensive, if the specifications contain any excessively severe or impossible provisions, the bidder is apt to infer that they are put there for the purpose of driving out all but favored contractors. Any ambiguity in specifying the quality of workmanship or material is apt to be construed by the bidder as against himself, and he will make his price to correspond. The city should take all risks which

do not properly belong to the contractor, because the bidder is likely to fix his price on the assumption that the risks go against him, whereas if the city assume a risk, it gets the benefit of any favorable condition that may arise. Especially the more competent and responsible contractors are apt to bid high or refuse to bid altogether on an extra hazardous job, unless work is very scarce.

The terms of payment should be as liberal as possible consistent with proper protection of the interests of the city and should be clearly understood beforehand. If the contractor is required to carry heavy financial burdens for a long time he will add the interest on this money to his bid. As the city can usually borrow money more cheaply than a contractor, if indeed, it has not the money already on hand, it can bear these burdens more cheaply than the contractor. The city is generally safe in paying for all material by monthly payments as soon as it is delivered at the site, or at the contractor's works, provided it is in such shape that it can not be used on any other work, or even if it is delivered at the contractor's works in crude form, if the city has a representative who will see that it is not used for any other purpose. After material has thus been paid for by the city, if it is used for any other purpose, a criminal prosecution could doubtless be brought against the contractor.

The law ordinarily requires that work of this kind shall be advertised, but it is not commonly done except in local papers, which are not usually adequate for this class of work. To supplement this it is a good plan for the engineer to send copies of the advertisement to any competent contractors whom he may know. If the work is of considerable magnitude, difficulty, or complication, ample time should be allowed the contractor to investigate the work fully and make proper estimates in order to submit an intelligent bid. The engineer should give each bidder any information in his possession which could help him in making his bid, but should be careful to give the same information to all bidders, as a failure to do so might invalidate the contract.

Excessive bonds should not be required, as it imposes an unnecessary burden on a contractor, the cost of which he will add to his bid. The bond of a surety company is usually to be preferred to a personal bond, because it is less liable to lead to political complications. The engineer, however, seldom has any choice in that matter.

If the job is of any considerable magnitude, it is almost always best to let the masonry, the steel work, and the paving separately, better prices will usually be obtained by that course. But if the work is such that it is important that the different contractors should work in harmony with each other, it is often better to let the work to a general contractor, in which case if he sublets part of it, it will be to men with whom he can work in harmony, thus saving considerable time and frequently much litigation.

If the plans for the work are prepared in full detail, it is better to let the contract for a lump sum with a unit price for additional work. In case the foundations have to be carried deeper than shown on the plans, any parts of the work, the quantities of which can not be accurately ascertained beforehand, should be let at unit prices. This method is generally more equitable and less liable to involve disputes than any other. It is well to provide that the city receive tracings of all shop drawings before final payment is made on the job. These are much more useful than blue prints in case repairs or alterations are needed at any future time. As the money due for public work is not liable to attachment, and as public structures are not subject to mechanics liens, it is not necessary to make provision for these in the contract.

Although perhaps not strictly his duty it is often well to see to it that the necessary right of way is obtained in ample time, and it is usually his duty to make satisfactory arrangements with the owners of any private property which his bridge may cross. If the construction of the bridge involves the opening of a new street and it is desirable to build it before all buildings are cleared away under condemnation

proceedings, it is frequently possible for him to make arrangements with the parties interested to clear the way for the structure in advance of legal proceedings, but in doing so he must bear in mind that the rights of a lessee are as important as those of the owner of the property. Such agreements made with the engineer by property owners need not in any way affect their rights under subsequent legal proceedings. In crossing railroad tracks and similar property it is well, if practicable, to make satisfactory arrangements with them as to the design and method of erection of the bridge. Although the city has power to condemn a crossing over a railroad, it has no right to obstruct its right of way, and if the crossing is made with the approval of the railroad officials, the damages assessed against the city will in general be nominal, if anything at all is said about them. Besides, the railway officials are generally in position to do much to facilitate or hinder the construction of a bridge across their tracks. In the construction of bridges across navigable streams, the approval of the War Department must be obtained for the plans as well as the method of erection.

In the construction of public works the law gives very large powers to the officials in charge and they often have ample power to ruin any contractor on their work, therefore, as a point of honor it is well for the engineer to treat the contractor at all times with absolute fairness. If, moreover, the engineer has a reputation for oppressive conduct toward contractors, that fact will be reflected in the unduly high prices which the city has to pay for work constructed under his supervision, besides, the best class of contractors will often refuse to bid on his work. It is almost always specified in public contracts that the decision of the engineer shall be final in questions relating to the construction, or amounts due under the contract. The courts will usually uphold his decision in such cases, always under the conditions that he is acting in good faith and within his powers. If his decisions are attacked on these grounds, the burden of proof rests with the contractor. The courts recognize that a public

official is often under strong temptation to yield to the wishes of an influential contractor and are in the habit of presuming him to be right and giving him all possible support.

The city has no right to allow any portion of a bridge, as for instance, sidewalk brackets, coping, pilasters, etc., to project over the building line onto private property. If such projections are allowed to remain without protest for twenty one years, the city acquires an indefeasible right to the property thus occupied; although I doubt if many city officials would care to enforce a right thus obtained. The acquisition of right by prescription can be prevented by a proper written contract between the city and the property owner. The city can acquire rights against private property owners by prescription or adverse possession, but private parties can not acquire rights against the public in the same way. This is legal principle that has been established for centuries. The theory of the law being that private property is looked after better than public, and if some such safeguard were not thrown around the rights of the public in its streets, the carelessness or dishonesty of public officials would eventually deprive the public of the use of a large portion of its streets and roads.

The time of completion should be fixed in the contract, and it is usual to specify the amount of damages for delay; this, however, is not essential because the court will oniy allow actual damages, if they can be ascertained. Whatever the contract may provide, the court reserves to itself the right to inflict penalties. The city has a right to open traffic on the bridge as soon as it is in condition to do so, and this will act in mitigation of damages for delay in completion. This does not constitute an acceptance of the work, but after that the city can collect little more than the inspector's salary and some nominal damages for delay. The only way, in many cases to insure final completion in a reasonable time is to withhold a considerable part of the contract price.

Every engineer in charge of construction should know something of the legal principles involved in his work; not

for the purpose of being his own lawyer ("For the man who is his own lawyer has a fool for his client.") but he needs the knowledge to help him keep out of lawsuits. If he, unfortunately, gets into one, he wants as much of the law as possible on his side. He should bear in mind that success in litigation depends largely on the ability of counsel. Many a litigant has lost a good case because it was not well handled.

The type of bridge to be adopted for a given place is often difficult to decide. I am inclined to think that esthetic considerations should have at least as much weight in the design of a bridge as in that of a public building. It is fully as conspicuous and often about as permanent. It is difficult, if not impossible, to design a beautiful steel viaduct. Reinforced concrete is little, if any, more expensive, is much more durable, and can be made quite attractive. A well designed suspension bridge or steel arch is beautiful where it is suitable, but the most beautiful of all is the masonry arch. It will bear any reasonable amount of ornamentation and has an appearance of stability and durability that is unequaled by any other type of bridge. Its first cost is high, but its durability is so great that in the long run it is very economical. A well-designed plate girder span looks very well. It is very difficult to design a good-looking Pratt truss on account of the essential ugliness of the portal bracing; and if it is considerably skewed, which is frequently the case, it is decidedly ugly.

When deep valleys are to be crossed by viaducts, substantial looking stone abutments should be built of sufficient height and length to be somewhat conspicuous. This adds to their appearance and is advisable also because it reduces the liability of the partially concealed spots next the abutment from becoming receptacles for various kinds of rubbish and filth. If the viaduct is of stone it is usually well to relieve the flat side walls with suitable pilasters, or with a belt course at or near the springing line of the arches, and a coping, preferably dressed, with perhaps a moulding below and a neat and substantial parapet or balustrade above. This para-

pet should contain pedestals for lamp posts or other ornaments at suitable intervals. If the viaduct is of reinforced concrete it can be faced with stone or possibly brick, which is especially suitable for the soffits of arches, being less liable to leakage and interfering less with the steel reinforcement. Concrete can moreover be made very handsome itself by suitable mouldings and paneling, but no attempt should be made to imitate stone, as the sham becomes apparent in a few years if it is not from the first, and then will always appear ridiculous. Very nice effects can be produced by coloring concrete, but few engineers are competent to design that class of work. It would often be good policy to employ a competent architect to design the artistic details and to consult with him on the general proportions of any important bridge that is to be built. If a reinforced concrete viaduct is built it will often be found economical to build the side walls light, with longitudinal walls ten to fifteen feet apart between them, and the whole floored over with reinforced concrete slabs and without earth filling in the haunches of the arches. In this case the spandrel walls do not have to be designed as retaining walls. It is well to build all masonry bridges with three feet or more of earth filling above the crowns of the arches, and over the reinforced concrete slabs if they are used for flooring, to provide for pipes, etc. which may subsequently be required. It is in most cases a good plan to place sewer drops at the ends of a bridge connecting to a convenient sewer, or, if there is no sewer within reach, construct one.

A very cheap crossing for a deep ravine is to build side walls of concrete, preferably just inside the building line, with cross walls joining them, about fifteen feet apart, and floor the whole over with reinforced concrete slabs. These side walls should extend up to form a railing. Passages can be provided for streets or streams of water at very moderate expense. A great blank wall like that does not possess an attractive appearance unless relieved by pilasters, belt courses, or other ornamental features. This construction can be de-

signed so as to be almost as cheap as a steel viaduct with a wooden floor of the same width, and will carry much heavier loads, be much more durable, and cost far less for maintenance. If a masonry arch is built with openings through the spandrels they reduce considerably the strength of the arch under concentrated loads.

The ordinary steel viaduct is cheap and unsightly. The steel arch with viaduct approaches, if well designed, is a very handsome structure for crossing a deep hollow. Both these structures should be built with the piers of ample height so that no subsequent land slides, or washouts, will cover them up and bring the earth in contact with the steel, owing to the danger of bending the bottom struts and on account of the corrosion that will be produced. It is better to build isolated piers than walls extending clear across a bent because they are less liable to be covered up or even overthrown by earth sliding or washing down against them. The foundations of all side hill piers should be carried down to ample depth to prevent them from being undermined by erosion or land slides. But little ornamentation is suitable on bridges of this type beyond a neat steel railing on the bridge, a steel or stone railing on the abutments, with perhaps, a stone pedestal at the ends of the wing walls for a lamp post or other ornament.

Long span bridges crossing navigable streams being, perhaps, the most conspicuous structures in the city, should receive most careful architectural treatment. Some designers appear to think that the more sinuosities they put in the chords of a bridge, the more beautiful it is. I think, however, that although a curved outline generally looks better, the curve should be as simple as is consistent with reasonable economy; a bridge that is extravagant in design is hardly ever beautiful. The Pratt truss is not particularly beautiful, but can sometimes be used in manufacturing districts and other places where it corresponds with its surroundings. The Pettit truss has a more graceful outline and is better adapted to long spans. The suspension span is perhaps the

best for spans exceeding seven or eight hundred feet. It has a very graceful appearance, is quite economical and is well adapted for architectural treatment. The cantilever, well designed, is quite a handsome structure, but vibrates more than a suspension span, otherwise it resembles it quite closely. The steel arch is a very handsome type and is very economical where it is possible to build suitable skewbacks.

Very little ornamentation is called for on the steel work, except that the railing should be well designed and the towers of suspension and cantilever bridges will bear considerable ornamentation. A tasteful but not too elaborate portal may be built. The piers should be substantial looking and will bear considerable decoration; they should be pointed both on the upstream and down stream ends where there is any considerable current passing under them. The abutments should be artistically designed and should be of substantial stonemasonry. They should preferably have stone parapet walls, and a well designed tower on each wing wall, with possibly a certain amount of statuary. The massive masonry arched portals which are so common on the great bridges built in Europe are relics of the days when it was necessary to fortify all bridges and are hardly suitable in this country.

The railing of a bridge should be of sufficient height for protection but not so high but that a person can readily see over it. It is sometimes well to incline it considerably inwards at the top to prevent children from climbing over it, or it may be well to make the body of the railing of vertical parallel bars for the same reason. There should be no openings larger than about six inches wide, otherwise small children might crawl through. If a stone railing is built the same rule should be observed as to openings, and the projecting coping at the top will prevent children climbing over it; the inside should be dressed so as not to injure the clothing of pedestrians; it is well to finish the top with a slope of about thirty degrees so boys cannot walk on it. All railings, of course, should be of tasteful design, and not only be but

also look substantial. Although very often done it is seldom necessary to put a railing on the curb line, its principal use there being generally to furnish a roosting place for loafers.

City bridge floors should, wherever practicable, be paved, if the traffic is heavy enough to justify it. Plank floors are expensive to keep in repair, besides being rough and unsightly after they are somewhat worn; they are also apt to break through and injure horses' legs. A durable cheap floor consists of reinforced concrete slabs placed on the stringers, or cross beams, and covered with asphalt paving. This is somewhat heavier than plank floor, and rather more expensive, but the cost of maintenance is so much less that in the long run it is more economical. It has the further advantage that it is water proof and prevents the drainage from the roadway, which is quite corrosive from rusting the steelwork beneath. Other good methods of constructing floors are by buckled plates or beams covered with flat plates; these, like the reinforced concrete slabs, can be covered with any suitable paving; they also furnish a better support for street rails if they are required. If a plank floor is used; white oak or yellow pine are good for joists. The flooring may be laid in two thicknesses where the traffic is very heavy, the plank rots more quickly but is not so apt to break through. If the traffic is light, a single thickness of plank is better and the plank should not generally be more than about eight inches wide. I have so far been able to find no wood to compare with white oak for this purpose. Good white oak, however, is becoming very scarce in this part of the country.

For paving, asphalt can be used if there are no street-car tracks and the grade does not exceed four or five per cent., and the traffic is heavy enough to keep the asphalt in good order. Asphalt being only three inches thick is lighter than any other paving. Some varieties of asphalt requiring no binder are only two inches thick, the binder being one inch thick. If asphalt paving is used where there are street car tracks it is generally best to put a row of stone blocks on each side of the rails. Where the grade exceeds four or five per

cent. and the traffic is very heavy, block stone is perhaps, the only suitable material. Where the traffic is light, brick may be used. Wood blocks, which are better if creosoted, make an excellent pavement where the grade is not too heavy; they are much lighter than brick or stone and about as durable. They will stand a very heavy traffic and can be used next to street rails. All these pavements should be laid on concrete foundation, which may be reinforced if required to be laid as slabs. Masonry bridges should, of course, be paved the same as ordinary streets. The side walks may be built of white oak plank which should be laid crosswise of the bridge and about a quarter of an inch apart, and should be dressed to uniform thickness. If the spaces between them are wider than a quarter inch people can see through them to the ground or water beneath, and some nervous people cannot bear that. If the planks are laid lengthwise it is almost impossible to wheel a baby carriage across the bridge, besides the ends lift up and people stumble over them. Cement is the best material for side walks with which I am acquainted. It can be laid as reinforced concrete slabs faced with mortar or on buckled plates. Asphalt was formerly much used but it is not so durable as cement, costs about as much, and, if any steel work comes up through it contracts away from it, leaving a place where damp dust lodges and corrodes the steel work very rapidly. Cement, on the contrary, adheres closely to the steel and protects it from corrosion. If plank sidewalks are laid, it is well to protect the curbs with steel angles, about 4 by 3 by ⅜, with the 3 inch leg turned down to form the curb and 4 inch leg horizontal on top of the side walk plank, and secured to it by ½ inch lag screws about 2 feet apart through the horizontal leg only. If they pass through the vertical leg, it is very difficult to get the curb angle loose to permit the putting in of new sidewalk planks owing to the fact that the screws rust firmly in the oak plank in a short time. If the sidewalk is of cement, which seldom occurs except where the road way is paved, a

cement curb is almost always the best. It is hardly ever necessary to face it with steel.

It is very important to thoroughly drain the spandrels of masonry bridges, especially where they cross over streets. They should be drained by means of pipes leading down through the piers into sewers, the backing of the arches should be made thoroughly water proof, preferably by a coating of strong cement mortar, asphalt is not durable in such places, and any leakage or drainage through the haunches of an arch produces dirty icicles in the winter, and unsightly incrustations in summer.

The question of paint on bridges is very vexatious. There is no question that the steel work should be thoroughly cleaned and the paint carefully applied; but these are rules which are sometimes difficult to enforce. The sand blast process for cleaning is the most thorough with which I am acquainted, but it costs so much more than hand cleaning that the city is hardly justified in going to the expense except, perhaps, in special cases. As to the kind of paint; it is difficult to make satisfactory trials because of different conditions, it being almost impossible to make the conditions as to workmanship, exposure, etc., sufficiently uniform in different cases to make a fair test. Those who know the most about that subject contradict each other flatly. Probably the best paint for priming on steel is a good red lead mixed in raw linseed oil, for the other coats, a good graphite or lamp black paint is to be preferred where the black color is not objectionable; the light olive green and similar shades contain so little graphite that they are little, if any, better than other kinds of paint. White lead containing forty or fifty per cent of white zinc is doubtless the best white pigment. For mixed colors it is a good plan to get the body paint in paste form, or mixed, and the other pigments dry and mix them on the work. Wherever practicable it is well to buy the oil and drier separate, using as little of the latter as possible; this procedure will do much to prevent fraud. It is a good plan to buy

all paints from reliable manufacturers and have chemical analyses made, as almost as much depends on the care and skill used in making the paint as on the quality and purity of the materials.

DISCUSSION.

L. J. Affelder, Member—It is not often, at a meeting of the Engineers' Society, that an opportunity to discuss the commercial side of engineering is offered, and I am very glad Mr. Whited brought up that phase of the subject. I, however, do not like his point of view. Most engineers, think that the consulting engineer, or city engineer, should be biased in favor of his client, the corporation, or individual, or city, and I think in that they err. My conception of the duties of an engineer, or architect, or anyone who draws up plans or specifications for public or private work is that he shall be unbiased in every particular and that he shall act, not simply as the agent of the owner, but as interpreter of the plans and specifications for the benefit of both parties to the contract. A contract is a mutual instrument, and in order that it may be a mutual instrument, the engineer who draws up a contract should consider the rights of the contractor as well as of the owner. The first requisite is as Mr. Whited has mentioned, that the plans and specifications must be complete, not only in justice to the owner or the city but in justice to the contractor. The average engineer or architect (I am going to make it general), assumes that the contractor he is doing business with is dishonest, and if such is the case, the contractor has a perfect right to do as he often does, take every honest advantage that he can of the owner or the engineer. If the engineer will be honest, not only with himself, not only with his client, but also with the other party to the contract, I think much better work will result. Besides that specifications should be just as complete as possible, there should be no loopholes for either party. There are many engineers and architects who draw plans and specifications in

incomplete form, and then try to get just as much out of the contractor as they possibly can. That is not fair to the contractor, but it is often resorted to, and for this reason it often becomes necessary for a contractor to even up on the second job. What I want to bring out is this: that the contractor is not inherently dishonest—the engineer often makes him so. He has got to do it to protect himself in many instances. I would like in this connection to protest against the protection which the speaker asks for the engineer or the city in fixing unit prices for different classes of work. I think in many instances that is done to cover up errors, and should not be resorted to. If the engineer will give the job the attention it deserves before bids are asked for, it would not be necessary to resort to such expedients. In steel work, for instance, it is often unfair to make changes and additions at a fixed price per pound, as additional cost of changes in the drawing, templates, etc., might be more than the entire cost of the additional material furnished.

I must agree with the speaker that contracts drawn by attorneys for engineering work are usually very poor instruments. They are verbose as a rule and very rarely to the point. An engineer who acts in a consulting capacity should be able, and is better able as a rule, to prepare contracts which explicitly state the conditions under which the work should be done.

The rule of rejecting the low bids I do not believe a good one. The same rule should apply to public work as to private work. Ask only those contractors to bid whom you would award the work. It is not only unfair to the contractors whose bids you would reject but it is unfair to put a responsible bidder in competition with an irresponsible bidder.

I would like at this time to say something about terms of payment which the speaker touched upon. There seems to be a general feeling, especially on public work, to pay as little as possible until the work is done. I think that is unfair to

the contractor. The contractor should be paid as the work progresses, not only at the site, but at the quarry, or at the bridge shop, or wherever the work is being done. On large work especially, I do not think it is fair to the contractor to ask him to carry too large a burden. I really believe that if terms of payment were more favorable on public work, that it would be done at a lower cost to the city. In fact, as a rule, the city has the money on hand with which to meet the payments and is receiving no interest on it, whereas the contractor must borrow money to carry on the work.

As regards extras, there is a general impression throughout the business world that a contractor delights in extras. I don't think so. I don't know how it is in other lines of business, but I know of one line of business in which an extra is usually unwelcome. The general impression is that there is a large percentage of profit on an extra. There may be a larger per cent of profit estimated in an extra than in the original contract. It is doubtful in my mind whether a contractor, unless he be unscrupulous, will make very much on extras, because it retards his operations and costs him considerable. I do not believe there is any excuse for the numerous extras that are made. As I said before, if an engineer, or an architect, or any one that is laying out work for others to execute will give that work the study and attention that it deserves, and will influence his client to allow him the proper time to get that work ready for the market, the cost of the work will be considerably less and the profit to the contractor will be considerably more.

C. B. Albree, Member—In regard to the question of payments, I know of a recent case where, on a large contract involving three or four million dollars, there was a great deal of material, running up into the thousands of tons, to be eventually used, but which could not be erected and placed until the majority of the other work was done, but the general contractor in submitting his estimate had to make up a price on these materials that would be used in two or three

years. In such cases he is dependent on the steel mills to stand back of the quotations they made at the time of his bid. My personal experience has been that it is very difficult to hold steel mills longer than a year. At present it is difficult to hold them thirty days on quotations. They state that the material has to be specified and shipped within a definite time; this works a hardship for the contractor, especially for a sub-contractor, because he cannot get his money until the work is in place. If he does not ship the material the mill price is liable to go up, or it is liable to go down; but on a rising market he is almost sure to be stuck. It seems that the risk should be eliminated by the city paying for that material. The material could be stored, perhaps at the contractor's risk as to rust or other damage. At all events it seems a case in which payment should be made for the material regardless of whether it is in place or not. Aside from that, there is the financial side— the matter of carrying two or three thousand tons of material for two or three years. With most concerns that would be a very serious matter.

G. H. Danforth, Member—I know of one case of work in New York City where they made partial payments as the work progressed, but the contractor in that case was paid a certain percentage on all material delivered by the mills to the shop; material at the shop ready to ship was paid for at another percentage; material shipped and delivered, but not erected, was paid for at a third percentage; and material erected was paid for at a fourth percentage. That enabled the contractor to carry quite a large contract without straining his finances. As far as I know of that case, it worked very well.

L. P. Blum, Member—It seems to me that when a municipality undertakes an improvement, funds are usually provided before actual construction is begun. As the city has the money, it is only simple justice to pay the contractor up to the highest percentage that is safe to pay. In other words the city ought to bear the financial burden, not the contractor.

While unit prices may work hardship in steel contracts, they furnish the only satisfactory method of payment in foundation work or work of similar character. No matter how accurately borings may be taken, and a preliminary estimate made, it is impossible to estimate quantities of foundation accurately enough to serve as the basis of a lump sum bid. Under such circumstances, if the contractor is compelled to put in a lump sum bid, he will surely bid high enough to protect himself from loss.

In a neighboring city, which I served a few years ago, we had peculiar sewer contracts. The contractor was compelled to bid for the sewer at a certain price per linear foot, with no extra price for foundation work required. What was the result? Contractors always bid a price high enough to cover the extreme amount of foundation which it would be necessary to put in, and anything saved from that extreme amount of foundation was clear profit.

The attempt of a municipality to make a contractor assume risks which properly belong to itself is usually unwise, and usually results in the city paying for what it does not get.

K. A. Mullenhoff, Member (by letter)—I agree heartily with the author in his condemnation of concrete made to imitate rock-faced stone. It is a sham. The French engineers, who are more artistic than any others, face nearly all their concrete structures with stone. Has Mr. Whited any experience that would indicate the comparative power of stone and concrete to resist the weather?

I have some doubt of the durability of reinforced concrete structures on account of their small mass, which makes them vibrate so much more than stone. The vibration might gradually disintegrate the concrete and separate it from the steel. This would allow the entrance of moisture, which, by corroding the steel, would cause the ultimate destruction of the structure, and that without warning.

For paving, yarra-yarra and other Australian woods are used quite successfully in Paris, Berlin and other cities. In

Berlin, it is quite common to provide space under the sidewalks of bridges for wires, pipes, etc. These spaces are covered with slabs of granite about 9 ft. by 7 ft. and 6 in. thick resting on small I beams.

WILLIS WHITED—Mr. Affelder mentioned one or two points that need a little explanation. This question of dealing fairly with the contractor I tried to put on the narrowest basis, the basis of self-interest. The ethical aspect of the matter makes it still stronger. I have known some contractors to put in very reasonable bills of extras while others pad theirs most outrageously. However, this asking for additional material hardly ever applies, to any great extent, to steelwork for bridges, but it is a good plan for something must be done to protect the city against extortion. It is used more on foundations and masonry work than anything else. Of course, that does not subject the contractor to any particular hardship.

In the matter of terms of payment, I can agree with both Mr. Affelder and Mr. Albree. I have always been in favor of allowing the contractor, when estimating, all materials that were in shape that could not be used on any other job, or, if he was asked to hold the materials for an unreasonable length of time owing to the masonry not being done, or some other delay, to allow him liberally for it.

I spoke of sending invitations around to bidders, but it is not strictly the engineer's duty to do that. It is always advertised, in fact the contract is not legal unless it is advertised, and the city engineer has no power to prevent anybody from bidding. Naturally we would not ask anybody to bid unless we were prepared to accept their bid if they made it in good faith. It is obviously necessary for the city to reserve the right to reject bids.

Mr. Mullenhoff asks as to the comparative durability of stone and concrete when exposed to the weather. I know of no concrete in this vicinity, excepting cement sidewalks, which has been exposed to the air more than four or five years. Most of these show numerous small cracks, but

whether they increase in size or number with age, or tend to the destruction of the structure, I am unable to say. None of them are old enough to prove much. The concrete work that is done now-a-days is so much better than what was done a few years ago, that experience with old work is of comparatively little value as indicating the probable durability of modern concrete structures.

The vibration of reinforced concrete structures should do no damage, for, if it is well designed, the greatest vibratory strains are well within the elastic limit. If corrosion of the steel should take place, since iron rust occupies about four times the volume of the iron from which it is made, and since iron expands with very great force in rusting, any serious amount of rusting would be revealed by cracks in the concrete.

*CHAIRMAN'S ADDRESS.

† E. K. MORSE.

The past year's experience, as Chairman of the Structural Section, has been a profitable one to me, and I wish to take this opportunity of thanking those of you who have attended the meetings and assisted in making them what they have been. It has been a disappointment to me, however, in that there was lacking that hearty support from some of the older members that I expected much from, and whose years of ripe experience should be counted in as assets of this Society, which has given many of them all the honors at her command, and the ethics of the case does neither excuse them from attendance nor for ever after contributing papers. There are members and varieties of occupations sufficent to make our meetings of the highest standard and most entertaining, if something could be done to bring about—may I call it the social side of our life? Is it cozy social quarters that are lacking? As I understand the subject it is the plain duty of the older engineers of this Society, most of whom are members of our National Societies, to assist and encourage the younger members, many of whom may never enjoy the privileges of any of the four great National Societies.

There have been some changes and shifting about in the ranks of the Engineers of the Structural Section, but none due to incompetence or lack of integrity have come to my attention. In fact when you look at our Society as a whole, it is most gratifying to know that in these days of get rich quick, scandal and graft, our members have stood the test unscathed.

This high standard of inbred integrity cannot be said to exist because the engineer lacks opportunities. What is it

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* Meeting of Structural Section, January 23, 1906.

† Farmers Bank Building, Pittsburgh, Pa.

then that makes our successful engineer entirely trustworthy, not only professionally, but in a moral sense as well?

The year 1905 witnessed the high tide of reinforced concrete construction. It is my opinion that there will follow a period of considerable weeding out of new types of construction, and that the adoption of both concrete for exposed positions and reinforced concrete in general will be carefully considered before being adopted. Do not for a moment understand me to mean that I am not in favor of either construction, but I do want it to be clearly understood, that I am by no means in favor of using concrete and reinforced concrete indiscriminately.

About ten years ago the structural engineer made a stampede from the uses of wrought iron to steel, and wonderful things were promised, somewhat the same as engineers of reinforced concrete of to-day talk, and it must be admitted that great steel bridges and buildings have been built. What about the maintenance and life of steel structures exposed to the climate conditions of this latitude? Only a few years ago it was noticed that paint would not stick on steel bridges and the universal cry was "poor paint!" Then it was discovered that it wasn't a question of paint at all, but it was due to the mill scale on steel that peeled off, paint and all. Now it is a fact that the rusting process goes on after the mill scale has been removed, the metal cleaned and freshly painted. A most careful inspection, made by one of our members last summer, of a steel bridge crossing the Ohio River, led to the discovery that in many places the horizontal legs of angles on floor beams, struts, etc., originally $\frac{5}{16}$ in. thick had rusted clear through, and in places disappeared entirely, all within the short space of eight years of highway travel, with the bridge kept in good, clean condition and well painted. Innumerable places all over this bridge were found where the original paint, and subsequent coats of paint, were in perfect condition, yet the steel section that it was supposed to protect was rapidly rusting away. This is not the only one, all steel bridges and

exposed structures are alike; subject to and undergoing the same process of destruction. The outcome of this will be, and that soon, we will either adopt wrought iron or the mills must roll a new structural metal.

The adoption of wrought iron would be a retrograde action. Nickle steel is not readily attacked by rust, but there isn't enough nickle in sight in the known world to meet such a demand. If by using one percent of nickle in wrought iron, the elastic limit could be brought up to that of bridge steel of to-day, it would seem like an ideal condition, and solve the problem of mill scale, rust, paint and a multitude of other serious objections to steel.

The good old fashioned high grade wrought iron gave the best known results up to date and will stand by all odds, the greatest amount of lack of attention with the minimum amount of damage.

The scarcity of timber is rapidly bringing about the adoption of a more permanent construction in the adoption of bridge floors, reinforced concrete bridges of short spans instead of plate girders and buildings in general.

There are other subjects, upon which I might dwell, fully as important as the two above mentioned, but which are not perhaps proper to discuss at this time.

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THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

*STEEL CROSS TIES.

†W. F. MILLER,

Member.

The question of cross ties is fast becoming the all absorbing question of the hour with engineers and railroad managers of the United States. Not that a change of material, composing the cross tie, is made necessary to keep apace with the march of progress, but in the consideration of the important question of track improvement, the growing scarcity of timber within our domain, has and will have much to do with any contemplated change of material in cross ties. We are not only facing the problem of an adequate supply of wooden ties for the newly developed railroads, but the more serious matter of procuring a sufficient supply of first class cross ties to facilitate the maintenance of railroads at present constructed and operated.

A large factor, in the depletion of the visible supply of wooden cross ties in several years past, has been the enormous construction of electric railways, and while they do not enter strictly into competition with the railroad cross tie,

* Meeting of Structural Section, Jan. 25, 1906.

† 407 4th Ave., Pittsburgh, Pa.

they come from the same forests and help reduce the visible supply of timber for cross tie purposes, and this scarcity necessarily and naturally means, as it has meant in the past, an increase in the cost of the wooden cross tie.

Owing to this menacing scarcity of timber, we shall of necessity, and in the natural order of things, be obliged to look for a cross tie composed of different material to supply the demands, as well to keep apace with the march of progress and invention in modern railroading, where improvements have been installed in every line; except that of the cross tie.

Where shall we look for the new cross tie to meet the requirements, and of what material shall it be composed? And how much longer shall we be contented with a track laid upon wooden ties, where safety, stability and efficiency depend upon the simple spike and splice-bar? If we look into this subject, with that degree of care which it warrants, it will be obvious that the steel, or metal, track of varied construction, and in some instances possibly accompanied by re-inforced concrete, will constitute the construction which the future will present to us as the guarantee of permanence, stability and efficiency in track construction.

Imperfections exist in the present construction of railroad track systems carrying heavy locomotives and rolling stock at short intervals and at speeds varying from 20 to 40 miles per hour for freight, and from 50 to 65 miles per hour for passenger trains. This is recognized by engineers and railroad managements everywhere, yet practically very little has been accomplished toward solving this important problem in railroad economy. The problem has been much discussed in the leading technical journals of this country and Europe. Patents have been procured by various and numerous inventors with a view to improvement upon the present conditions of track construction. These improvements have thus far consisted in substituting for the wooden cross tie, steel ties and steel and re-inforced concrete track construction of various types, but up to this time none of the various

types, to be utilized in track improvement, has the unqualified endorsement of any of the great railroad corporations of this country, possibly from the fact of the enormously increased cost of the initial installation.

It is a well known fact that for a number of years the railroads of Europe have been equipped with steel girders directly supporting the rails, and in some cases, for example in England, the rails were placed directly on top of long longitudinal girders constructed of rolled sections, but in later years, in that country, this type of construction has been entirely replaced by wooden ties which have been protected by a chemical preparation to preserve and prolong the life of the tie.

The use of steel longitudinals supporting the rails is confined almost entirely to Germany and Austria, where the majority of the railroad systems are owned and operated by their respective governments.

Quite a number of steel cross ties have been invented, and many are now in process of introduction as substitutes for the wooden cross tie. A few of these have in my opinion considerable merit. Enough, I should suggest, to warrant close and studious inspection and examination by engineers interested in this special branch of engineering, as well as managers and those who come in contact with construction and maintenance of railroad tracks.

I am aware that the first question which arises relative to the adoption of steel cross ties is that of cost. A majority of the steel cross ties in existence to-day are so expensive to manufacture, that railroad managers hesitate to consider the change to steel cross ties until the supply of wooden cross ties shall have been entirely exhausted, and they brought face to face with a new and unavoidable condition which shall then exist. Some say that most of the steel cross ties thus far brought to their notice contain so many parts, the intricacy of which will entail untold expense in maintenance. Others object because of the rigidity of the track structure, which eliminates that elasticity which facilitates and helps train

movement. Others are prone to look with disfavor upon the steel tie, and the attendant rigidity and non-elasticity of the track, as a menace to the motive power and rolling stock by reason of the extreme wear and tear produced by the attendant jar and pounding incident thereto, which will necessarily entail a much greater expense in the maintenance of the same. Others object to the metallic sound which they claim arises from a solid steel track structure. Others (forgetting that the steel tie is yet in the experiemental stage) argue upon the subject of corrosion, unmindful of the longer life of the steel cross tie and that the corrosion may be much reduced by the use of black tar, asphalt, graphite or some other suitable iron paint for the preservation of the tie, and of the fact that when the steel tie shall have been worn out and removed from the track it becomes scrap steel which constitutes a rebate of probably $15.00 per ton, and when we consider the enormous demand for cross ties to be used in the maintenance of the track mileage of the United States, amounting now to about 35,000,000 cross ties per annum, the rebate from scrap will constitute a considerable item.

There is at present in place about 67,000 steel cross ties upon the railroad systems of the United States, of which the Carnegie Steel Company have made and installed 47,000, and the same company has orders upon its books for 90,000 more for delivery this year.

The life of the steel cross tie is as yet an unknown quantity, and it would be a waste of time to go into this phase of the question until after a sufficient time shall have elapsed to prove the stability and lasting qualities of this type of cross tie, or at least until we can compute a certain time limit and conditions as a factor in theoretically determining their longevity, as I believe the chemical elements contained in the material surrounding the steel tie, as well as those of the atmosphere, will have a bearing on the case.

The question of insulation, in the use of the steel cross tie, so that they shall not interfere with track circuits in the manipulation of electric signals etc.; has also been spoken

of, but this will appeal to the average engineer and electrician as of minor importance, as the cable systems, lately introduced upon some of our western railroads, have proven so much more satisfactory to them than rail circuits that the question of insulation need not enter into the practicability of the use of steel cross ties.

It is not my intention, at this time, to enter into the merits of any special discovery, or invention, in the line of steel cross ties. I have succeeded in having placed before the Society, for its better edification, a few pictures and drawings of the types of steel ties which seem to be attracting the attention of the larger number of those interested in the

Fig. 1.

subject, and as the general use of the steel cross tie is yet virtually in its incipient state, I shall not attempt to enter the technical field to any extent, contenting myself with giving short general descriptions of these few types.

TRUSS STEEL TIE.

In Fig. 1, the upper flange of the I beam tie is cut in angular form on either side of the point at which the rail crosses the tie, and demonstrates the frictional principle upon which the clip and hook-bolt, shown in Fig. 2, when properly tightened up with the nut, holds the rail to gauge with a view to impossibility of slipping, owing to the constantly increasing

angle in the upper flange of the tie, which widens outward from the bottom flange of the rail when in place and forms in this respect a wedge. The clip and hook bolt is absolutely all there is to this mode of fastening (and this attachment, you will observe, is applied to non-insulated and fiber insulated ties) and the strength of it, as well as its adjustability and simplicity, are matters for your inspection and judgment. You will also observe that the inventor has carefully avoided the use of "rights" and "lefts" in these fastenings to avoid any

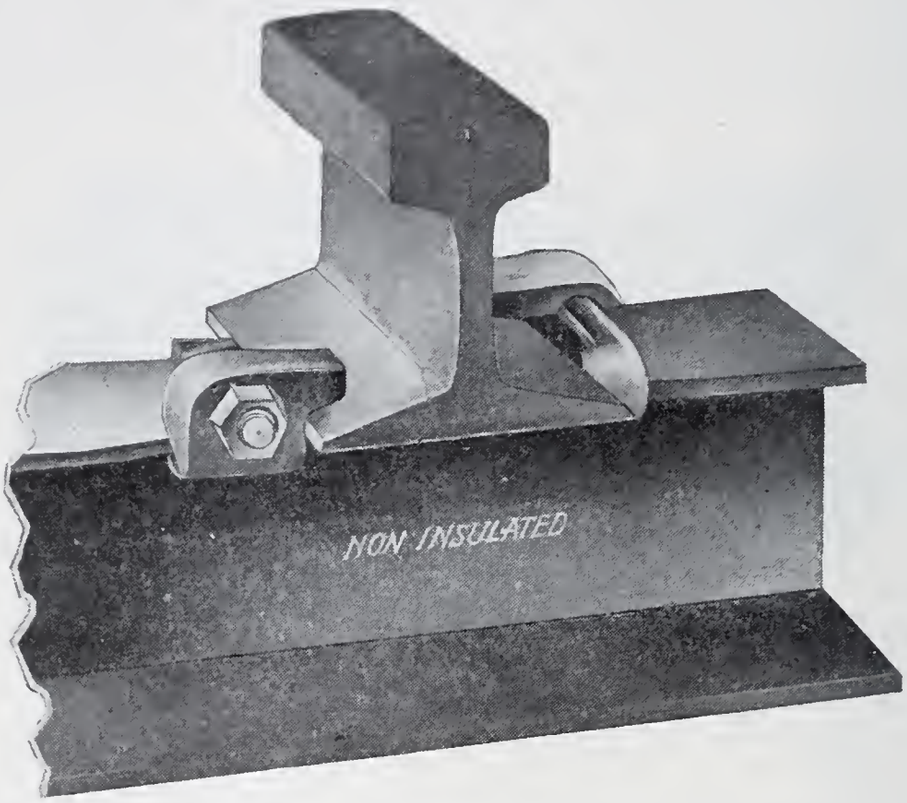


Fig. 2.

mistakes in attaching them to the rails. These fastenings are easy to install and remove and are easy of access. The clip and hook bolt have a play along the angular cut flange on the head of the tie, of at least one inch on either side of the rail seats on either end of the tie, making in all four inches of shifting space to acquire gauge, being ample in any case for the difference of gauge on tangents or curves as used in railroad practice, or for changes from lighter to heavier rails. Perhaps one of the most valuable features of this clip and hook bolt attachment is its position. Lying horizontally, it

is not subject to the violent strains produced by the jar and vibration to the track structure, as the vertical bolt and nut are subjected to under the same conditions. The owners of this type of steel tie tell me that their experience with this system has shown that where these fastenings have been in use for four months, in no instance has it been necessary to tighten up the nuts, though the fastenings have been subjected to very violent strain, particularly where heavy tonnage on curves of small radii has tested their merit as to stability.

Fig. 3.

Fig. 3 shows the same principle applied to an insulated tie, made necessary in safeguarding the electric circuit where signals are to be operated by a current conducted through the rails. This, of course, is intended to prevent leakage and short circuiting because of the metal ties. This insulation seems complete. You will observe that these ties are rolled in the form of a modified I beam, 5½ in. deep, 8 in. lower flange, 4½ in. upper flange, ¼ in. web, and weigh about 20 lbs. per lineal foot or about 160 lbs. per tie. They have a sectional area of 6 square inches, and are identical in section with the Carnegie Steel Co.'s tie which I shall take up later, and being

FIG. 4.
Steel Ties on P. & L. E. R. R. at McKees Rocks, Pa.

so the same laboratory tests as shall be shown in the case of one will apply to the other.

The spacing of the ties by this system, as shown by Fig. 4, differs from that in common use. There are 10 cross ties to each 30 foot rail and the ties are laid to form a horizontal triangular truss system, which makes the track uniformly and exceptionally rigid and causes it to resist lateral forces and motions. At the centre of the longer spaces formed by the triangular spacing of the ties, the rail is supported by a cast iron chair, three feet long and the same height as the tie. Thus it will be seen that the centres of the rail supports in this system are about eighteen inches apart. I might further add that there are sections of track laid with this cross tie in the New York subway at 148th St. and Lenox Ave.; upon the Pittsburgh & Lake Erie R. R. at McKees Rocks, Pa.; and upon the Bessemer & Lake Erie R. R. at Euclid, Pa. Fig. 5.

THE M'CUNE STEEL TIE.

This cross tie is manufactured from $\frac{3}{16}$th inch plate or sheet steel pressed in box girder shape, with the four corners of the box girder, on the under or slotted surface, turned downward at right angles 2 in. to form an anchorage for the cross tie in the ballast, in order to prevent side or end movement of the tie, and to preserve the track alignment. On the top surface of this tie the central portion is depressed one inch for a distance equal to that between the outer edges of the lower flanges of the rails when in place, forming a shoulder which acts as a rail brace and at the same time fixes the gauge of the track. The inner side of the shoulder thus formed, forms a lock for the square headed bolts, which, being inserted through holes in the top of the tie, hold the rail clamps on the outer sides of the rails. The clamps on the outer sides of the rails are constructed of ¼ in. sheet steel, pressed and bent to fit the lower flange of the rail, the shoulder in the tie and the top of tie, and contain bolt holes and slotted outer ends to permit of the central portion being bent upward to act as a

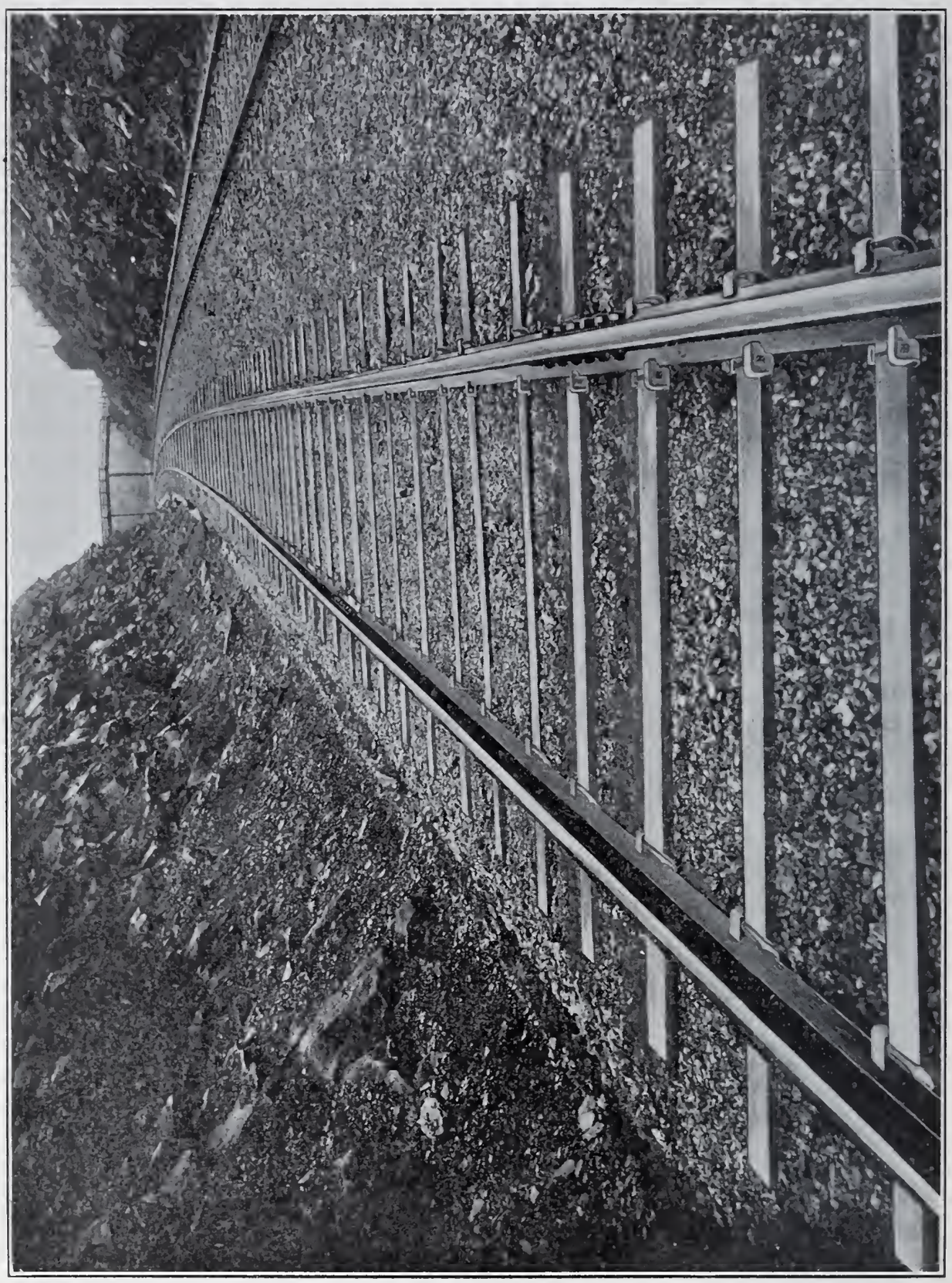


FIG. 5. Steel Ties on Bessemer Railroad at Euclid, Pa.

nut lock for the upper or outside nut used upon these clamps. The clamps on the inner sides of the rails are formed by using the same sized bolts and the same thickness of sheet steel as those on the outside, but differ in that on the inside of the tie a flat piece of sheet steel is inserted the full width of the inside of the tie, the centre of which is stamped to form two lugs at right angles to the plate, which forms the lock for the bolt head on the inside of the tie. The bolt inserted through this plate, and through a hole in the top of the depressed portion of the tie and the flanged rail clamp having the same slotted nut lock as the outside clamps contain, forms the complete inside rail clamp. The weight of this tie when complete is 97 lbs. and is very simple in construction. This tie has considerably more elasticity than the I beam ties.

Fig. 6, P, refers to side view of tie, showing the positive shoulder, or rail brace, with clamps to hold rails. R, refers to top view of tie and location of clamps. S, refers to the bottom of the tie, showing opening in same, and location of turned down corners. The broken part shows inside arrangement of clamps and bolt. T, is an end view of the tie, showing corners turned down. Fig. 7 shows top view of tie with rails attached and Fig. 8 shows the bottom view of the same.

A section of the main track of the Monongahela Connecting Railroad near the furnaces of Jones and Laughlin Steel Co. on 2nd Ave. this city, has been laid with this type of steel cross tie which has been in constant use for the past nine months, enduring the strain of some of the heaviest traffic known to modern railroading. The ties being on a 1% grade and part on a 16 degree curve and part on a tangent to it. Fig 9 is a view of this piece of track and shows the perfect alignment after nine months' use.

The inventor of this cross tie claims that the depression on the top of his tie, which forms the shoulders, composes a positive brace for the rails, entirely eliminating the possibility of rail spreading. He also claims that on account of the weight of the tie they are easily and cheaply installed and removed, cheaply maintained, and from the larger amount of

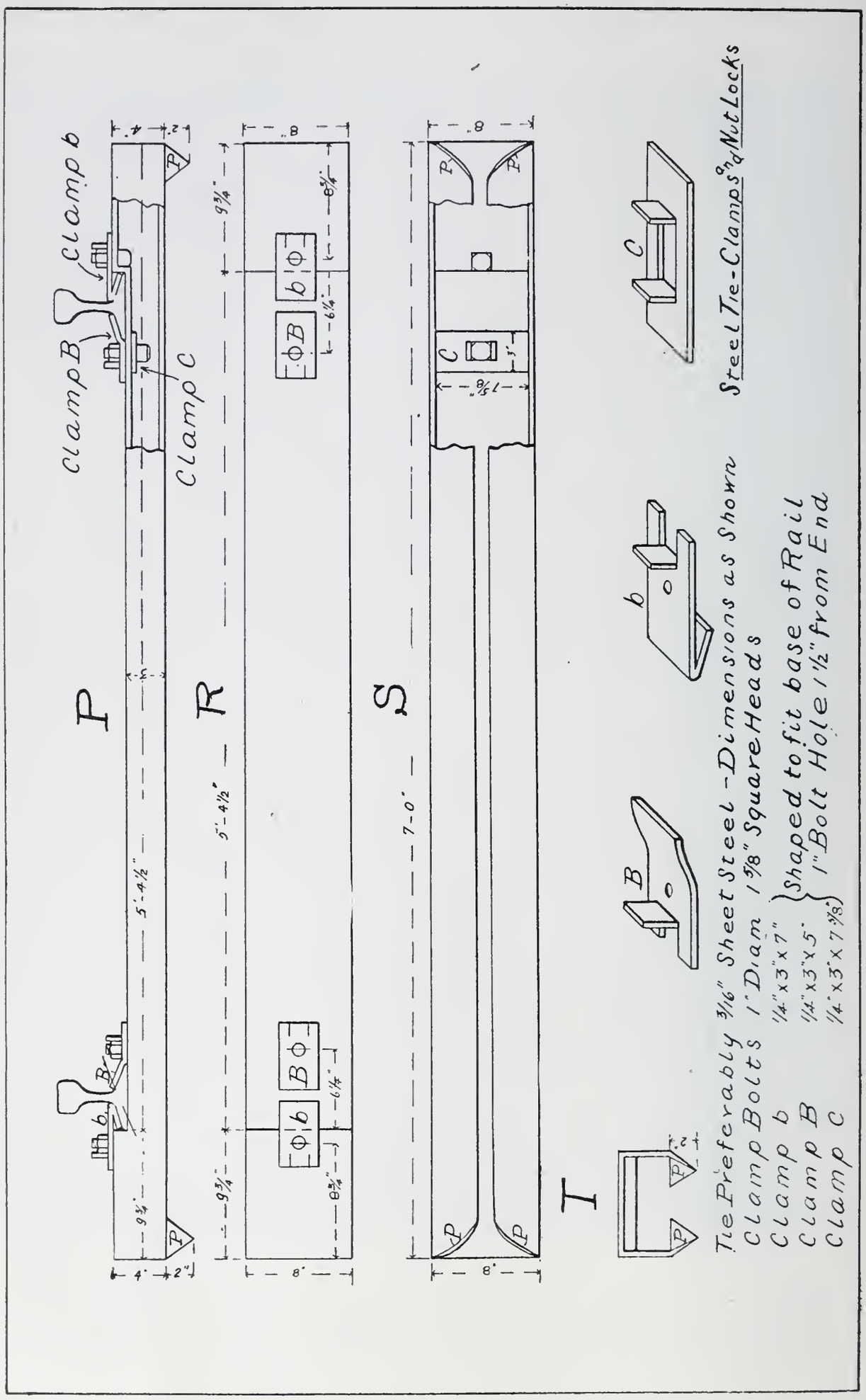

Clamp b
Clamp B
Clamp C
P
R
S
I
5'-4½"
7'-0"
Steel Tie-Clamps and Nut Locks
Tie Preferably 3/16" Sheet Steel - Dimensions as Shown
Clamp Bolts 1" Diam 1 5/8" Square Heads
Clamp b 1/4"x3"x7"
Clamp B 1/4"x3"x5"
Clamp C 1/4"x3"x7 5/8"
Shaped to fit base of Rail
1" Bolt Hole 1½" from End

FIG. 6.

elasticity displayed will work a great saving to motive power and rolling stock and will help train movement, especially on curves and grades.

THE CARNEGIE STEEL CO.'S STEEL TIE.

This tie, Figs. 10 and 11, is rolled in the form of a modified I beam, is 5 in. deep, 8 in. lower flange, 4½ in. upper flange, ¼ in. web, and weighs 19.7 lbs. per lineal foot or 167.4 lbs. per tie.

TOP VIEW

Showing Clamp Attachment

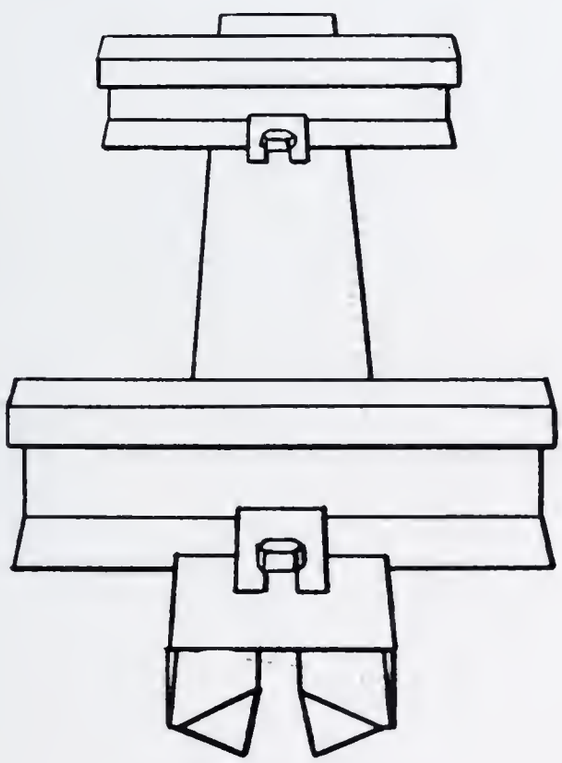


FIG. 7.

There are four holes punched in each end at one operation by means of twin punches, thereby assuring accuracy in the gauge. The outer group of holes take care of the joints, while the inner group take care of the intermediate points on the rail. All these holes are punched in each tie in order that they may be placed anywhere in the track, whether at a joint, or at

an intermediate point on the rail. The lower flange of the tie, or its base, is crimped at a point 6 inches from each end with a view to holding the tie in line. Fig. 12 shows how the rail is secured to the tie with four ¾ in. bolts by means of rolled steel clips fitting accurately on the flange of the rail, and having a bevel exactly the same as that of the flange. They are carefully punched so that the shoulder of the clip gives proper and positive rail alignment. The claim that this tie is about as easily installed as the wooden tie is made by this company.

INVERTED

Showing Bottom View

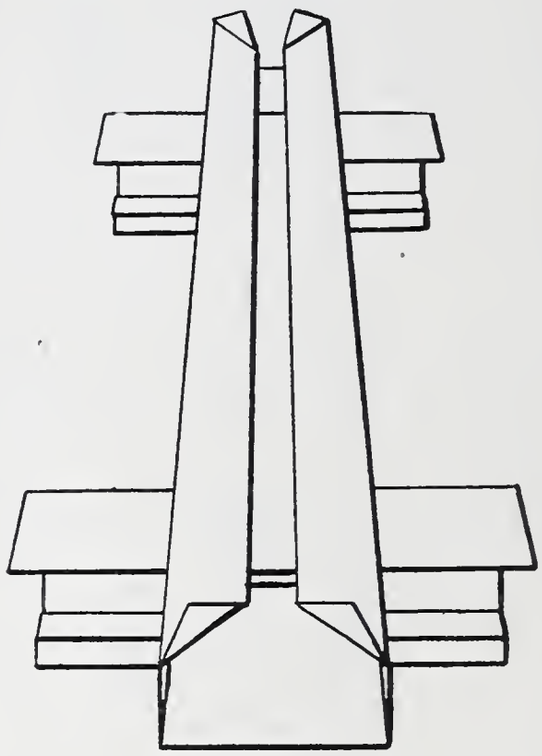


FIG. 8.

Laboratory tests which have been made on this tie show that a load of 170,000 lbs. can be placed upon it before there are any signs of failure, and it required 240,000 lbs. to put the tie in condition to be no longer serviceable.

A test was also made with this tie standing on end with load applied on the edge of the rail, and it was found that at

Fig. 9.
Steel Ties on Monongahela Connecting Railroad, Pittsburgh, Pa.

17,500 lbs. the top flange began to buckle, permitting the rail to release itself. This in comparison with the white oak cross tie was as follows: Where two spikes were used to fasten the rail to the tie, the rail released itself at an average of 4,700 lbs., where four spikes were used a failure was recorded at 12,500 lbs.

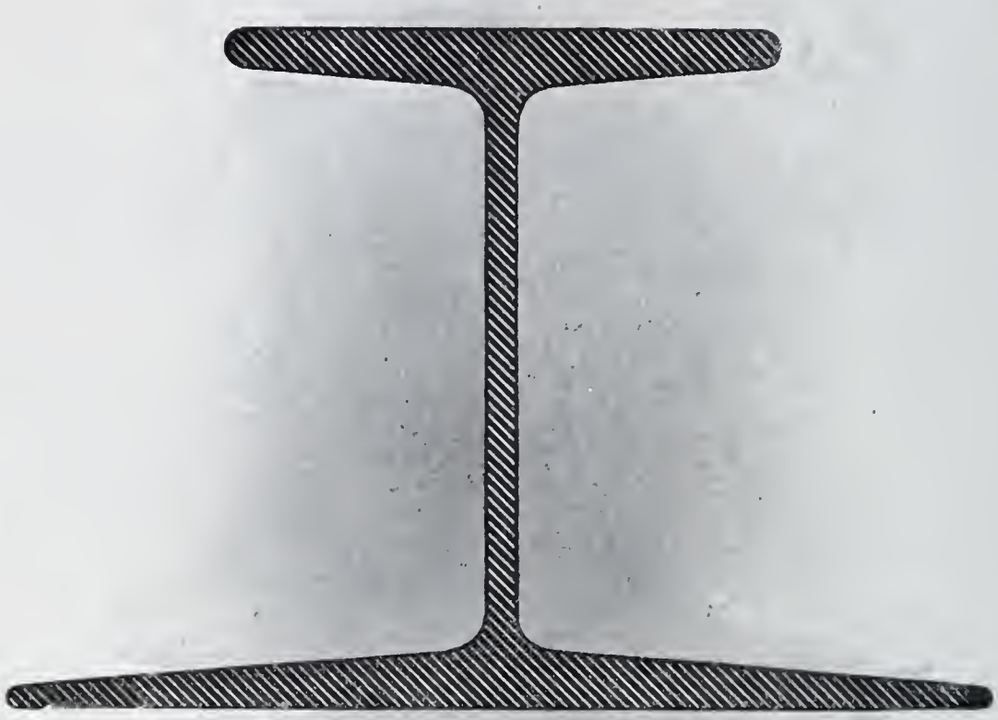
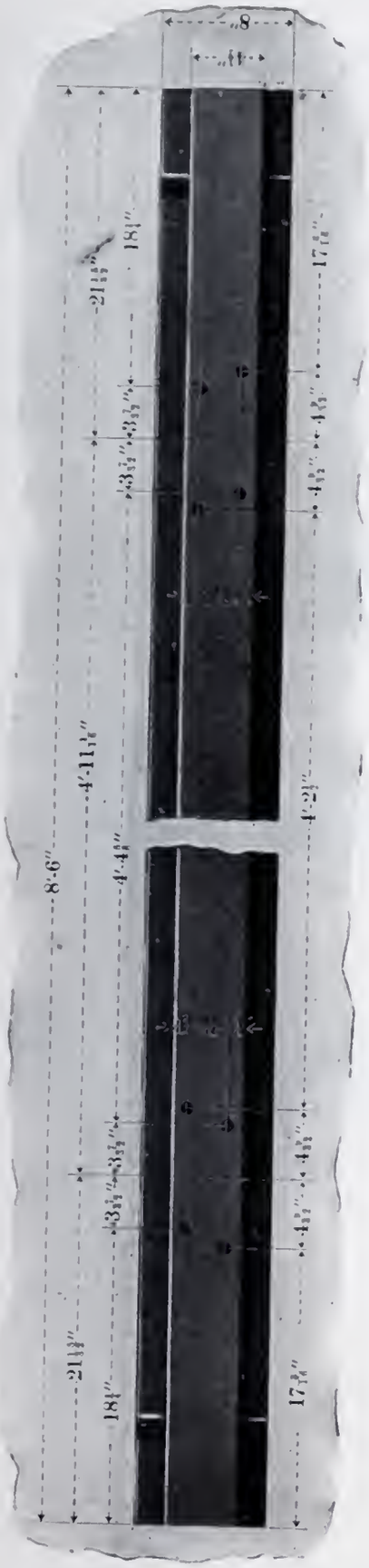


FIG. 10.

Section of Steel Tie. Depth, 5 in.; lower flange, 8 in.; upper flange, 4½ in.; web, ¼ in.; weight, 19.7 lbs. per ft.

It is claimed by this company that on curves there is more uniform wear in the rail with the use of their tie than at points where the wooden ties are used, and they attribute this to the fact that the entire track is of mechanical structure, uniform throughout. They also claim that they can get a uni-



Top view of Tie.

Gauge—4′-8½″ for 85 lb. A. S. C. E. Rail.

Side view of Tie.

FIG. 11.

form gauge, which they cannot attain by the installation of wooden ties.

This tie has been installed in sections upon the following roads upon which it is claimed satisfactory results have been attained.

Duluth & Iron Range R. R., near Duluth, Minn. Bessemer & Lake Erie R. R., at Euclid, Pa. New York Central & Hudson River R. R., near Rensselaer, N. Y. Lake Shore & Michigan Southern R. R., near Silver Creek, N. Y., and near La Porte, Ind. Pennsylvania Lines, near Emsworth, Pa. Pittsburg Railways Co., at 9th Street and Penn Ave., Pittsburgh, Pa. Fig. 13 shows a view of the tie in use on the N. Y. C. R. R.

It has been my aim to present the subject of steel cross ties to you from an unbiased and pecuniarily disinterested standpoint, and if I have succeeded in awakening a sufficient interest in the question to move you in the direction of criticism, acquiescence or discussion, I shall consider that the objects I have labored to bring about shall have been fully realized.

DISCUSSION.

*H. T. Porter, Non-Member—September, 1904, the Bessemer Railroad received about 1,200 I beam ties, 1,000 of these were put in the track two miles north of Euclid station, during Nov. and Dec., 1904, and Jan., 1905. The track at this point was laid with 100 lb. A. S. C. E. rail, and with hewn white oak ties about six years old, on six to eight inches of slag ballast. The ties were put in by the section gang without any effort to put this track in any better condition than it was before. We did not give the section foreman any additional ballast, and as the space occupied by the steel ties was so much smaller than that occupied by the wooden ties, there was hardly enough ballast to half fill the track. Between Nov., 1904, and June, 1905, the road was single track at this point, and carried the entire tonnage of the Bessemer Railroad.

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* Bessemer Railroad, Greenville, Pa,

In June, 1905, the second track was put into operation, and since that time it has simply carried the south bound tonnage. As south bound trains are operated with pushers at this

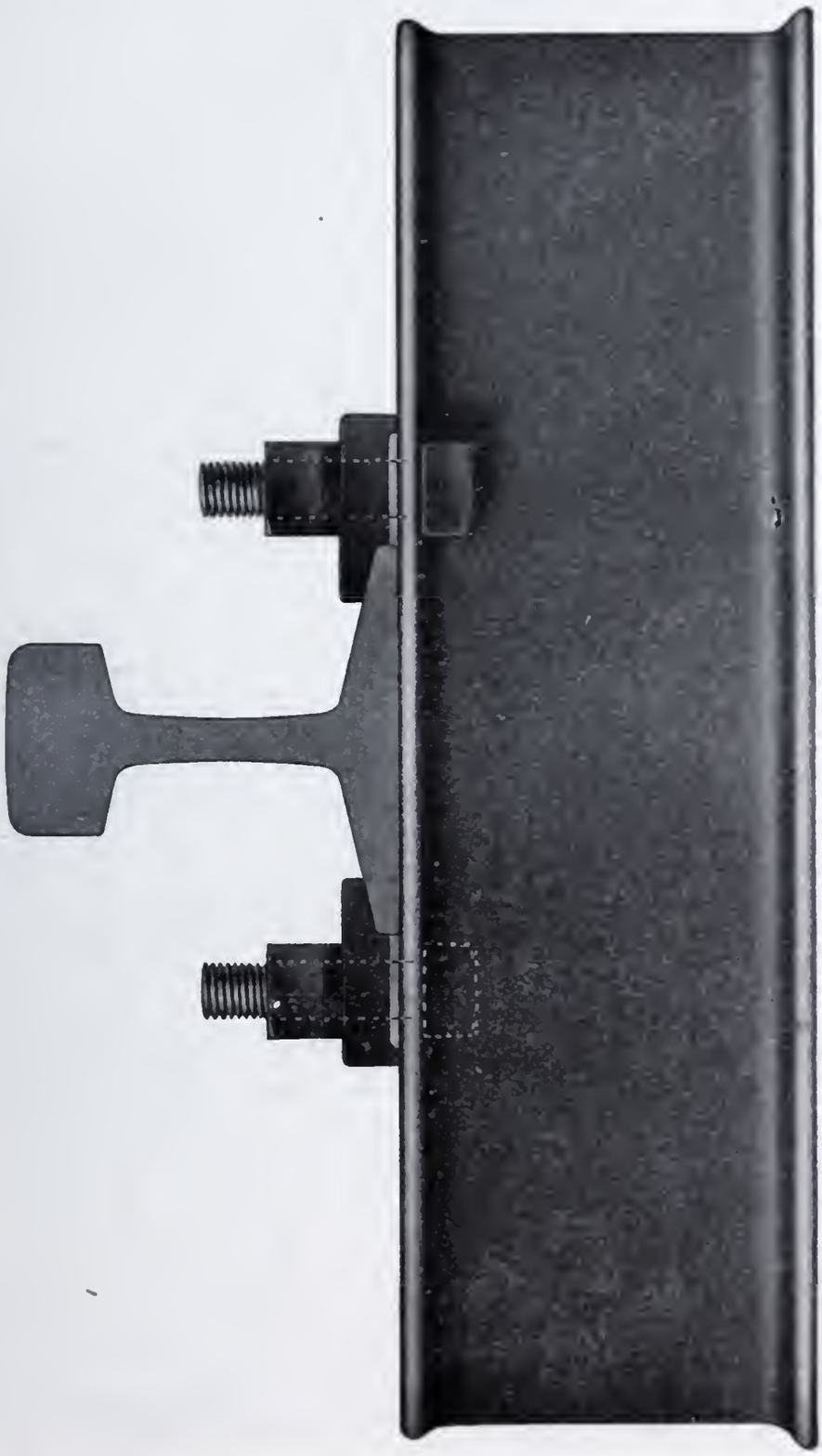

Fig. 12.

point, up until June, 1905, it not only had the pushers going south over these ties, but also backing up. The most of these ties were on a four degree curve. The Supervisor re-

Fig. 13.
Steel Tie on N. Y. C. R. R. at Castleton, New York.

ports that after the steel ties were put in on this curve, he had much less trouble keeping the track in line than he did before; notwithstanding it was only half filled with ballast.

The latter part of Aug., 1905, we began receiving steel ties on an order for 25,000. Dec., 1905, we completed laying our south bound track between Claytonia and Queen Junction, a distance of 4.4 miles, with steel ties, except three switches. We have not used any switch ties yet, but will begin putting them in this spring. There was put in last fall, between the above points, 9,863 steel ties. It cost 2.3 cents per tie to handle and distribute them, and 17 cents per tie to put them in the track. The 17 cents for putting them in the track does not include the cost of loading up, and taking away, the wooden ties that were removed. These ties were spaced 14 to the 30 foot rail, and 16 to the 33 foot rail. After laying this stretch of steel ties we re-ballasted the track with slag. They are giving very satisfactory service, and we expect to get, during this year, about 80,000, which will make a total of about 106,000.

I simply mention these figures to indicate that we have faith in the steel tie, and that we expect to secure enough return in the way of better track, and future economical maintenance, to justify the expenditure. We are using them in construction tracks, laying the ties right on the mud; just the same as we would with the wooden ties. We are using steel ties under all conditions that a wooden tie would be used.

As to the future economy, I have done a little figuring. I took the Interstate reports, for the five years ending 1900, and I find the tie renewals cost 2.3 times as much as the rail renewals. On the assumption that the steel tie can be produced at about the same price per pound as the steel rail can, and on the assumption that the life of the steel tie will be fifty per cent greater than the life of the steel rail, the cost of tie renewal would only equal the cost of rail renewal. We have not had sufficient experience in this country to determine the actual life of the steel tie, but on the Continent, experience

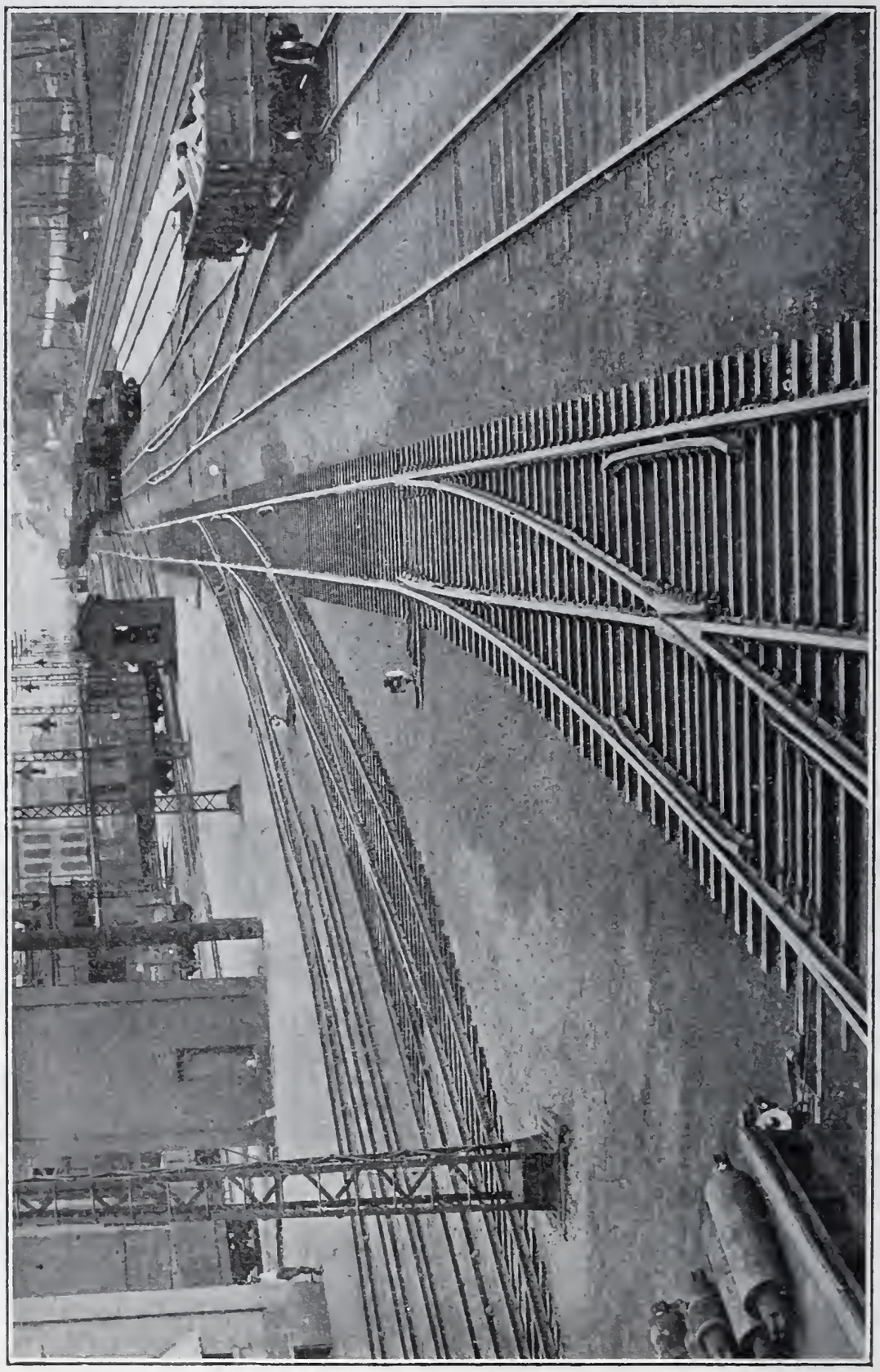

Fig. 14.
Steel Tie used in Switches.

has shown that my estimate is conservative. If the renewal of ties for the five years cost 2.3 as much as the rail renewals, and if it can be reduced to the same cost as the rail renewals, it shows there is a great possible economy in the use of the steel tie.

E. K. Morse, Member—What is the operation like? With the wooden tie, unless the road bed is very fine, there is a considerable wave motion ahead of the moving train. Is that load uniformly distributed with the steel tie?

Do you expect to use these ties for switching purposes, turnouts and special work?

Have they been in long enough to detect the effect of climatic change?

How is the steel tie going to affect the maintenance?

H. T. Porter—As far as the surface is concerned it is dependent upon the amount of bearing upon the ballast. The benefit of the steel tie, I think, will be in the fact that the steel tie will not deteriorate after you once get the track up and the ballast under it thoroughly tamped. The surface and line is usually disturbed by the tie deteriorating. After four to six years the ties deteriorate rapidly. The rail wears into the wood tie and the tie gets smaller, so it is necessary to keep resurfacing, which disturbs, more or less, the solid bed formed. I think with the steel tie you will get rid of this.

The Carnegie Steel Company have 28 sets of steel switch ties at Homestead and they are very satisfactory. Fig. 14 shows the steel tie so used.

The first ties were put in in Nov., 1904, so they have been in during the winter of 1904-5, and so far this winter. That covers nearly all kinds of weather conditions there.

We expect to see a reduction in maintenance, in cost of labor for surfacing and lining, and sufficient increase in the length of the life of the tie, to make the steel tie more economical than the wood tie. Our observation of the steel tie track, is that it is much more substantial than the wooden tie track.

K. A. Muellenhoff, Member—What kind of soil do you have under your ballast?

H. T. Porter—At this curve the roadbed was very near the surface of the ground, there are some places where there is a light cut; other places where there is a light fill. We formerly had more or less trouble in keeping up the track, but since putting in the steel ties, the Supervisor reported it cost considerable less to line that track up, and keep it in line, than it did before.

*A. Granville, Non-Member—The economical question of ties is one of the important things to determine—whether or not, the steel tie can be purchased at such a cost, that it becomes of advantage to railroads to use it in place of the

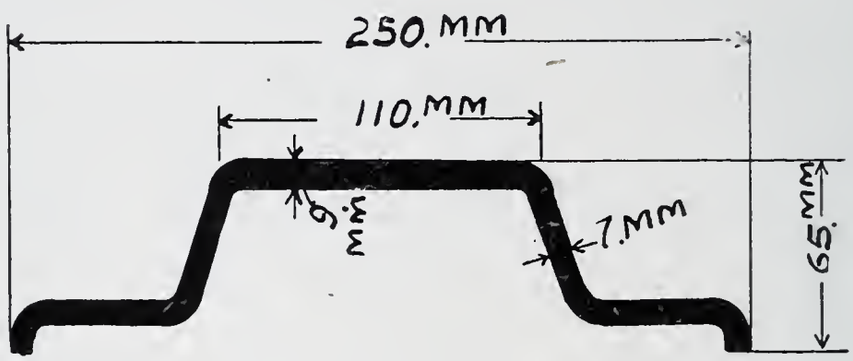

Fig. 15.
Harmann, 49.5 lbs. per yard.

wooden tie. The question is: Does it pay? Has the time arrived, from a commercial standpoint, when, other conditions being equal, the railroads of the country can afford to take up the question in a serious manner, and decide upon using the metal article in the place of wood.

In order to answer these questions satisfactorily, there are just two things which we must consider:

First, the price of the steel tie, as compared with the wood tie, and second, the length of life of the two materials. As to the first condition, I take it that a price of 80 cents per tie would be considered as a fair figure for the wooden tie, with the four spikes which accompany it, thrown in, although as a matter of fact I believe this

* Schmidt Bldg., Pittsburgh, Pa.

to be a very conservative estimate. The steel tie of the I beam form, with the necessary fastenings, can be furnished for $2.40 apiece, so that the cost of the steel tie is just three times that of the wooden tie, which would, at first thought, seem to make it prohibitive. But the life of the steel tie is five or six times that of its wooden competitor, which is about five or six years under the most favorable circumstances. The steel tie, under constant use, has a record of 30 years, and even more, while two prominent steel men in this country have estimated the life of the steel tie as 40, and possibly 50 years.

Allowing 2,880 ties to the mile, which will permit of them being placed 22 inches apart from center to center:

Cost of installing one mile of road with wood ties and spikes, at 80 cents per tie	$ 2,304 00
Cost of maintenance for six years at $550 per year	3,300 00
Interest on investment for 6 years at 4½%	618 20
	$ 6,222 20
For a period of 30 years (the life of the steel tie) the total cost of wood ties and maintenance	$31,111 00
Cost of installing 1 mile of steel ties with fastenings etc.,	6,912 00
Cost of maintenance for 30 years	3,300 00
Interest on investment for 30 years at 4½%	9,334 20
	$19,546 20
Deducting for 100 tons of scrap at end of 30 years	1,500 00
	$18,046 20
Difference in favor of steel ties	$13,064 80

It will be seen, from these figures, that a road constructed with steel ties will cost $6,912 per mile as compared with a standard road of present construction costing $2,304.00; but taking into consideration the long life of the steel tie, as com-

pared with the life of the wood tie it is evident, that the advantage lies greatly with the steel tie, while the cost of the maintenance of the two different ties, is in inverse ratio to the cost as just stated per mile of track.

FRANK MCCUNE, Member—The Monongahela Connecting Railroad have had a section of steel ties, designed by the speaker, in service for over 7 months, in a portion of the west bound main track ,on the point of a 16 degree curve where traffic is extremely heavy, over 100 trains and engines passing over it each day. We have 200 cars with a capacity of 100 tons each among our individual car equipment, and several of our largest engines weigh 120 tons in working order. These

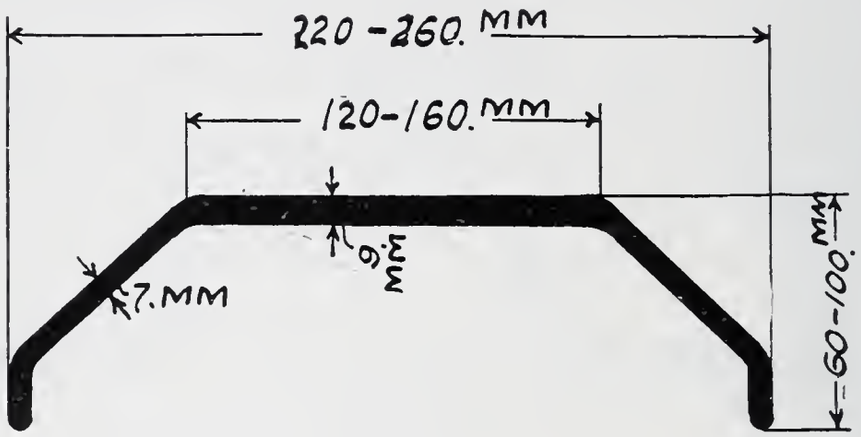

FIG. 16.
Hilf, 46-70 lbs. per yard.

cars, loaded with ore and pig iron, are handled daily over the track where these steel ties are in service. In 7 months this track has not moved a sixteenth of an inch out of line where the steel ties have been placed, and there has been no repair work during the above time on this section of the track. The line and surface is perfect. The elasticity of the tie allows the rails and ties to work in harmony, and thus save wear to rails, ties, rolling stock and machinery. This feature is the improvement over any of the rigid steel or wooden ties. The road bed in which these ties are laid is granulated slag.

E. K. MORSE—I would like to emphasize one thing, which Mr. McCune did not bring out, and that is, the marked sympathy of elasticity between the rail and the tie, noticing, under those heavy 240,000 lbs. car load, the great deflection

concentrated on a few feet of the rolling load on the wooden ties. The moment it strikes the track with steel ties there is an elastic sympathy between the rail and the tie that is most marked. It does seem to me that a whole track of steel ties, made of that one uniform material, must add an immense amount to the life of the rolling stock. We see our rails and switches pounded to pieces, sometimes in a few weeks at Jones & Laughlins. With this excessive loading on sharp curves on wooden ties, the punishment is something terrible, and the punishment to the financial end is rather severe.

In 1887, near Carlsruhe, Germany, I saw wrought iron ties in use on a railroad, where they had, perhaps, two or three

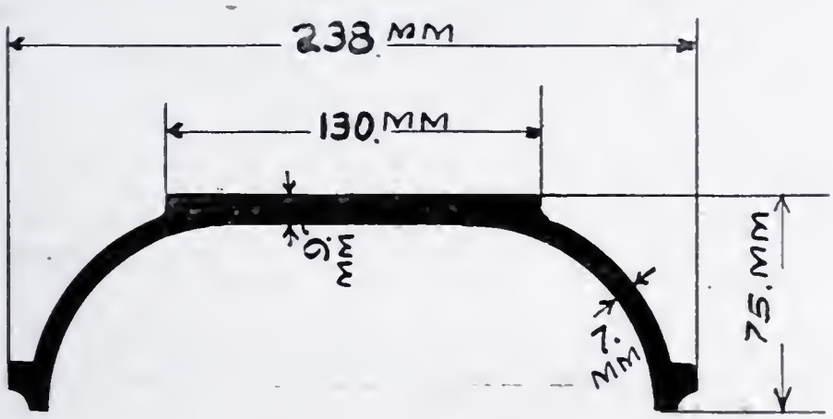

FIG. 17.
Kupfer, 55.6 lbs. per yard.

miles of them. The ties were of an octagonal section, with the ends turned down to prevent lateral motion; they were ballasted with gravel. I understood they were discarded later as a failure. The Germans called them "squirt-guns," as in the spring time the water would get in, and when the train would pass over them, the water would squirt out for a considerable distance. They had trouble with the rails spreading, and they could not hold the alignment.

K. A. MUELLENHOFF—As I remember, the first steel ties used were of a similar shape to the Carnegie tie and were used in Belgium, but the experiment was not very successful, as the ties had not elasticity enough. During the great railroad boom in Germany, in the seventies, they took up the idea of steel ties, first in connection with the longitudinal tie.

These were not successful, they also made cross ties. One of the earliest forms to be used was the Harman tie, Fig. 15, It was not stiff enough, difficult for tamping, and the lateral stability was too small. Then Mr. Hilf developed, from his longitudinal tie, the form shown in Fig 16, and Mr. Kupfer, the tie in Fig. 17, which has been adopted by the Gotthard Railroad. The standard tie of the Prussian State Railroads is similar to these types; they are all bent down at the ends as shown in Fig. 18, to keep the track from moving sideways; by this bending the end is flattened at the same time, increasing the bearing surface. In Europe they incline the rails at

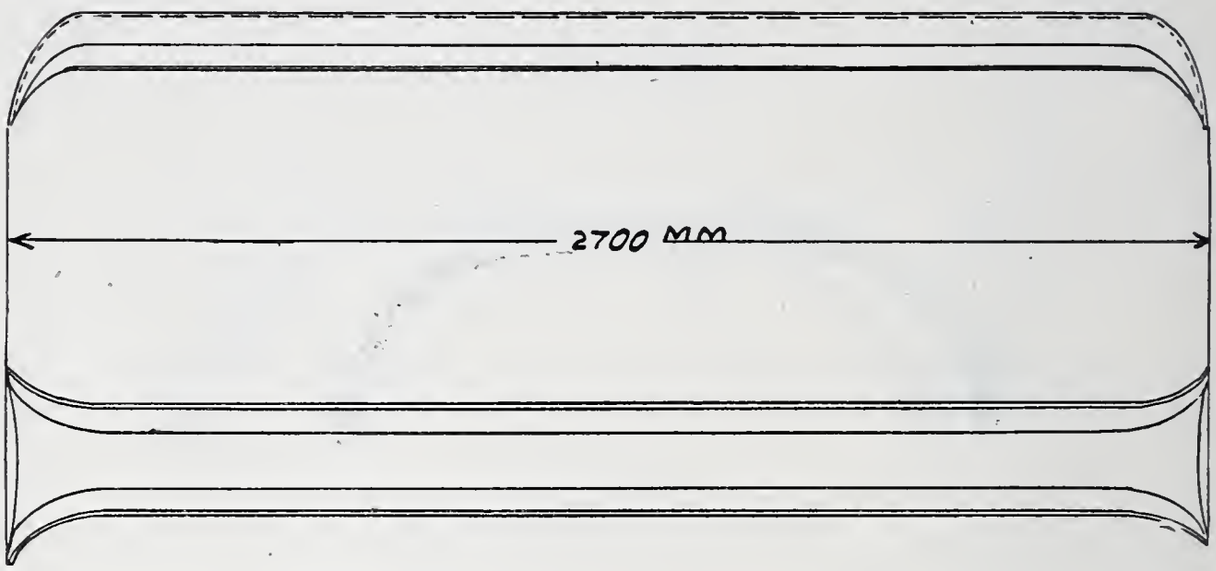

Fig. 18.

about 1 in 20 in order to give greater lateral stability. They tried to bend the tie at its centre to the required angle, but this made the tamping very difficult, and so they were forced to introduce special tie plates, connected firmly with the tie, and holding the rail rigidly in its proper position. The Prussian State Railroads have developed an especially complete and simple system of fastening, requiring but very few parts, which may easily be kept in stock.

The ties are rolled, cut to their proper lengths and pressed in one heat, and before cooling they get a coat of asphaltum or tar. If the ballast is good, and there is sufficient drainage, they will certainly last 25 or 30 years.

*CENTRAL STATION POWER.

† F. F. ESPENSCHIED, JR.,

Non-Member.

By central station we mean a power house supplying electric current to the public, and at the present day it is usually alternating current. The Edison stations, however, are an exception.

Before the perfection of the induction motor, such a station had to rely on a lighting load almost exclusively. It is naturally uneconomical to provide a heavy equipment, suitable to take care of the large evening peak and the lesser all night municipal lighting, and then have scarcely any load during the working day. Many small plants still close down in the morning and resume again at nightfall.

The central station finds little difficulty in getting plenty of load during the evening and well on through the night, but the great dip in the load curve when the street arcs go off in the morning, means also a dip in the possible return on the investment.

To fill up this half of the 24 hours the station must sell to power users, and, since the machinery must be installed of sufficient capacity to care for the evening peak, it is possible to sell at a lower rate during the day than during the period of lighting load. I dare say that if a consumer wanted to run a 500 horse power induction motor from the service lines only from 5 P. M. to 10 P. M., the station would have to charge him an exorbitant price. Increasing the number of revenue producing hours enables the station to sell current at a lower rate during the peak than it would be able

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* Meeting Mechanical Section, February 6, 1906.

† West Penn Railways Company, Connellsville, Pa.

to sell it for if all the revenue had to be made during a shorter period. In this way a power load on the station is an advantage to all the consumers. Increased revenue comes from a large volume of daylight power or motor business.

In this section of the country, where coal and natural gas are so cheap, it is naturally more difficult to secure power consumers than it is where fuel is high, although, on the other hand, where fuel is high there are usually less power users.

Usually we think of a steam driven central station, as feeding a large city, but we have, some sixty miles south of here, a plant of 12,000 horse power, supplying, by means of 22,000 volt lines, a chain of towns none of which exceed 20,000 in population. This is an ideal situation, being in the center of the coal and coke region, but it would seem almost useless to try and sell power, over as long as 35 miles of transmission line, to coal mines and coke works. It is a different proposition to fill out the daylight load here from what it is in a large city, where lights are used all day to some extent, and room is scarce in which to set up individual plants.

Where numerous manufactories are supplied by long aerial lines over rough country, continuous service is a prime requisite. The number of light users during the day being small, regulation is not as important during this period as it is toward evening. Fortunately, most plants close down about the time the lighting load comes on, although on short winter days the two overlap by an hour or two.

A short list will indicate some of the most important industries in this district: Coal mines and coke works, foundries, manufacturers of metal products, glass works, planing mills, breweries and ice plants, flour mills, miscellaneous small factories and users such as crushers, grinders, elevators, etc.

The coal mines use little machinery in cutting the coal, it being mostly mined by hand. Mules and horses are used for haulage in the mines, and as many mines are drifts in the sides of the hills, little more is required to get the coal to the

tipple. In the case of coke works, the coal is dumped from pockets into the larry, and run out over the ovens for charging, ovens being usually built so that the loads run with the grade. Some few, of the larger works of modern construction, have their own power plants supplying 250 volt direct current for mine locomotives, hoisting and larry work. Where the plant is new and operates well it is not easy, at first, to displace it with central station power, although more than one large gas coal company has recently discarded the steam engine entirely and put in central station current for the entire mine, with a marked saving in cost and an increased output. Usually the small coke works, with a drift into the adjacent hill, uses animal power to haul the cars and larries, and a little boiler plant to operate the fan and pumps where necessary. Mules and horses are expensive and work slow, so a good electric power proposition usually carries conviction to the manager. When this is the case, the owners decide on what they need in the way of locomotives and larry motors, and the station installs a motor-generator set of sufficient capacity to care for the equipment. An induction motor coupled to a 250 volt direct current generator is a very satisfactory set, although, because of the better effect on the line power factor, a synchronous set is much to be preferred. When the trolley line is near by, direct current is taken from it at about 500 volts, thus saving the motor generator set, although as a rule 250 volts is preferred in mining; but there is a growing tendency toward 550 volts and some of the larger mines are changing to that voltage. For operating the mine fan a variable speed 220 volt induction motor gives excellent service, either belted or geared to the fan, the proper size of the motor being readily obtained from the fan manufacturers, or by an indication of the engines driving it.

It is found that the average consumer does not know what he wants in the way of motors, and it is advisable for the station to render all possible assistance in the choice and installation of the machine, a charge being made only for the actual labor and material used.

One example, which is typical of a new coke works entirely electrically driven, has a hundred ovens in operation. Two larries equipped with 30 horse power, 550 volt motors charge the ovens. A rope haulage is used to draw the loads up the slope of the mine, and geared to the winding drum are two 75 horse power, 550 volt, series motors, equipped with the ordinary railway type series parallel controller. The mine pumps are all, in this case, air driven, the air being supplied by a 100 horse power, 2,200 volt, two speed induction motor, driving a Laidlaw Dunn Gordon two stage compressor, 18 in. by 11 in. by 18 in. The mine fan had a 40 horse power Bessemer gas engine, but a 15 horse power induction motor now handles it successfully. The direct current, at 550 volts, is obtained from the trolley line near by, and the alternating current from the 2,200 volt 2 phase mains. For plants remote from the trolley line it is necessary to supply a motor generator set, as it is still found advisable to use the direct current motor for haulage and locomotive work. Of all loads, a mine is perhaps the most fluctuating and consequently the hardest on the distribution system, particuarly when the motor in the set is of the induction type. A fortunate feature lies in the fact that the works only run during the day, the ovens being usually charged before night.

A second industry of great importance is the foundry, which is found in various sizes and sorts. Power is used on the elevator for charging the cupola , the load being heavy and intermittent. A motor for this service is easily chosen when we have the weight to be lifted, speed and approximate efficiency of the gearing.

Besides this there is the blower, crane, machine and pattern shop, emery wheels, tumblers and often an air compressor. We find such a plant usually driven by a steam or gas engine belted to a long line shaft, which in itself absorbs from 25% to 50% of the engine output. This offers exceptional opportunity for taking indicator cards of the various loads, throwing each section on, one at a time. One induction motor to each section gives a great saving in power ordi-

narily wasted in shafting; and makes the plant far more flexible. Altogether a foundry offers a fairly steady load on the lines.

The manufacture of metal products requires the machine shop, where the economy and flexibility of electric drive are well known. We find that managers of small shops prefer using group drive, where the line shafting is already installed, because of the smaller first cost. Induction motors, in a case like this, when of size sufficient to carry the maximum load, prove objectionable in that they are frequently run underload and consequently at a very poor power factor. A case recently came up where a shop containing three motors of 30, 20 and 15 horse power runs for considerable periods at a power factor of about 50%. An individual drive, where each motor works only as needed, would be a decided improvement to the line.

Glass works require power all over the plant, and as they are often spread over considerable ground the distribution of power by steam or shafting is very wasteful. The grinding and polishing wheels, arranged in rows, are usually driven from a jack-shaft to which it is easy to belt a motor. Such a load remains very constant, but is not well suited to individual motors.

Planing mills, containing high speed machines, usually have them arranged far apart and difficult to group for driving from one motor without much useless shafting. With these machines the highest speed, and consequently the cheapest, induction motor answers perfectly, the sizes being readily obtained from published data, or a test on the machine in actual operation. Even with the wasteful method of shaft driving, we have to consider that in many cases fuel costs nothing. At two plants recently tested the manager preferred to use electric drive, but they have so much saw-dust and shavings that it is cheaper to burn them for fuel under the boilers than to pay to have the refuse hauled away. However, most of the newer mills are adopting the electric drive exclusively on account of the greater output resulting.

In a plant requiring steam for boiling or cooking its product, it is little additional expense to operate the steam engine. The brewery is such a one and consequently few are electrically driven from central station mains. A brewery's power requirements are not large compared with the amount of the product. The ammonia compressor, pumps and elevators take most of the power. Ordinary ice and cold storage plants require steam, but there is less difficulty in closing with them. Ice making machinery operates evenly and for long hours; making a very desirable load.

Flour mills, where they are near enough to the lines, or large enough to warrant having a line built to them, make a good all day load. It is not difficult to obtain the horse power required by a test on the engine. Such mills usually run all their grinding and elevating machinery at one time, so where individual drive would not gain a customer, one or two large motors will replace the steam or gas engine and give far better service.

There are multitudes of small factories using central station power where a steam engine is too expensive to operate, and a gas engine too much trouble and too unreliable. With gas as low as 6c per 1,000 cubic feet, it proves quite a rival, but the noise, heat, and smell, besides cost of maintenance and uncertainty of operation of the engine, gives the motor a decided advantage.

For small installations, using motors of 5 horse power and below, it proves cheaper to the power company to install single phase motors, although the customer objects seriously to buying such a motor when the polyphase is cheaper for him.

Two phase distribution is employed by the station referred to, and where lights are needed in the plant using polyphase motors, one transformer is made large enough to take the lighting load beside its half of the power load. No bad results are noticed, save where the power load is very intermittent and the transformers are overloaded. In such a case a third transformer for light alone gives better ser-

vice, even when attached to the same lines as the power transformers.

In districts where business warrants it two separate polyphase circuits are employed, one for lighting and one for power. Where one only is used, a good automatic potential regulator is very necessary at the sub-station to take care of line drop due to load fluctuations.

By means of the aforementioned power consumers the load takes on a more even appearance all through the week, the difference between the daylight load and the evening load being greatly reduced from what it would be from lights alone. However, when we see the curve for Sunday, we wonder why the factories dont' work seven days instead of the usual six. The Sunday load remains largely one of transformer losses during the day and lighting at night.

DISCUSSION.

H. D. James, Member—The rapid advance which is taking place in the application of electrical power to industrial purposes, other than lighting, is little realized by those who are not actively connected with the industry.

One of the most noteworthy developments has been in the cotton and woolen industry of New England. The old method of delivering power, by means of a common shaft driven from the main steam engine, has now been superceded by the group drive connected to an alternating current induction motor. This latter arrangement has prevented serious delays in the mill due to minor accidents; it being possible to shut down one section of a room without disturbing the rest of the mill.

The application of electricity to mine hoists has not been extensively taken up in this country. We have a number of applications of an ordinary controller operated by hand, similar in its control to the valve of the steam engine, which

requires an experienced operator. With the application of electricity to mine hoists, it is practicable to develop a control system which will be entirely automatic, so that an inferior grade of labor can successfully operate it. Abroad, the development, in connection with electrical hoists, has been more advanced than in this country, and certain systems have been devised for equalizing the load on the power system by the use of a flywheel on a motor generator set supplying the hoist motor.

Electricity has also been applied to glass works, and this gives a very good illustration of the difficulties encountered due to the improper installation of apparatus. In the rolling of plate glass a large torque is required to start the roll, but the load immediately drops off to a small fraction of its original amount, and unless the speed of the motor is properly controlled, a wavy product is the result.

A. Stucki, Member—Mr. Espenschied spoke of machinery driven intermittently with gas engines and electric power in order to find out which is the most advantageous, and that finally the gas engine was set aside. Was the gas engine discontinued because it was not economical or was it due to some other conditions?

F. F. Espenschied—The bill for gas was less than the meter bill for electricity, but they found the gas engine could not be depended on.

H. D. James—I do not think it is fair to slander the gas engine. It is a mighty good machine, and many of the troubles experienced with it have been due to a lack of knowledge of its fundamental characteristics. Both the steam engine and the electric motor will carry a heavy overload under proper conditions. The gas engine, however, cannot be made to develop more power than its maximum rating. The gas engine people are using their best endeavors to impress this feature upon their prospective customers, but the old habit of buying an engine at its average rating rather than at the maximum rating, is still leading to trouble with the gas engine.

CHAS. H. ISRAEL, Member—The boiler people are making a waste heat boiler that utilizes the hot gases from coke ovens, with very little or no combustion under the boilers, generating sufficient steam, in one instance in mind, to supply two power houses, necessitating a steam line 1,600 feet long. Could you successfully meet a proposition like this with electricity from the central station?

F. F. ESPENSCHIED—We have not had such a proposition, but believe we could meet it.

GEO. H. HARLOW, Member—How do you get at the charge you make for your electricity?

F. F. ESPENSCHIED—We charge so much for each horse power installed, whether used or not, and in addition to that there is a low meter rate.

GEO. H. HARLOW—Don't you find it very difficult to get a manufacturing concern, which has its plant already installed with engines and boilers, to throw away their old plant and install electric appliances?

F. F. ESPENSCHIED—There is a plant at Jeannette where they have three or four steam engines and several gas engines that they have discarded. They replaced the steam engines by gas engines, and replaced the gas engines by electricity.

G. M. CAMPBELL, Member—It is rather remarkable that right in the heart of the cheapest natural facilities in the world, the cheapest coal and the cheapest gas, an electrical plant should start up to sell power to firms who have these very cheap facilities for making power of their own. It shows this firm must be very enterprising and manufacturing exceedingly economically to be able to cut out the local engines, gas and steam, and to supply local manufacturers with current at rates which not only approach local prices, but which are actually cheaper. The mere fact that a comparison between electrical power and gas at 6c per thousand feet can be entertained, shows that the rates charged for electric current must be low. I understood the speaker to point out that

they primarily started out with a lighting and railway load, and then endeavored to get a motor or industrial power load. Their office charges, and to a large extent their power house charges, were fixed by their general load. In order to get an extra profit it was necessary to sell a daylight load, and it is that part of the business that we have been hearing about to-night, the distribution of power for industrial purposes. The rate question brought up is an exceedingly interesting one and it is rather hard to grasp the various rate charges. It is not so much per horse power, not so much per meter rate. It depends largely on what part of the day and what part of the night you happen to want your load. If you want power when the heavy lighting load is on, you have got to pay stiff prices, but if you want power when the power house has but little load, then you can get it much cheaper.

F. F. Espenschied—Our commercial man is very busy trying to find some one who will use power on Sunday. Pleasure parks use but little in the summer and none in the winter. There are not enough people in that district to use it. The rate question is a very troublesome one to the consumer. I have had several say if the company would only cut off the demand rate and give them the same meter rate they would be perfectly satisfied. The fixed charges of the plant have to be paid and are usually paid for by the demand rate. If a man has the privilege of suddenly throwing on 500 horse power, it means the station has to be prepared to meet that demand at any time, but if we put the demand charge on it will keep down the likelihood of his suddenly throwing on such a heavy load. It has the tendency to keep down the power installed, as with the demand rate he is charged for the actual amount installed.

G. M. Campbell—Does not the demand rate have the effect of causing the consumer to buy less current?

F. F. Espenschied—It does not. The rate is so low that if you figure that the outside cost of power is the fixed charge plus the rate, you can easily determine whether it will be too

great an expense to put in the additional machinery. With the demand rate, he puts in the machinery that he actually needs, while under other circumstances he would perhaps put in machinery that he only needed once in a while, and he might take a notion to throw on all that machinery to the disadvantage of the power house.

L. C. Moore, Member—All this discussion has been on the question of the electrical generator as against the gas engine. I will venture to say the reciprocating engine is the prime mover in most of the cases, and I think we should say a word or two in its favor at this point in the discussion.

J. S. Lane, Non-Member—I have been a builder of reciprocating engines for a great many years, although I do not now manufacture them. A great many people have tried to scare us. They said when the gas engine came in it would knock us out; and the same thing when electricity was put into use. But instead of driving us out of the business, it has created a demand for more steam engines to run these generators.

In a town in Maine they put in a plant to light the city and to run trolley cars. They found the heavy load came at night, so they began to sell power, during the light load hours of the day, to the granite and marble people to run their cutters and grinders, and created quite a business in that way.

*THE ELECTRICAL TRANSMISSION OF POWER OVER GREAT DISTANCES.

† S. M. KINTNER,

Member.

The great development of electrical power transmission, during the past 12 or 15 years, has not been brought about by new discoveries of radically different machines or electrical principles, but on the contrary has been a natural growth in which a perfection of detail has been the most important element noticed.

From the time, only a few years ago, when the practicability of transmitting power electrically from Niagara Falls to Buffalo was so seriously questioned up to the present the electrical power transmission has been meeting with more and more favor. It has been spanning greater and greater distances until now we are face to face with a project in which 700 miles is the distance to be covered.

The experience gained during this development period has resulted in the adoption of an engineering practice that is quite generally recognized.

It is the purpose of the present paper to set forth in a very general way, an outline of such practice. The paper will not be found to contain much of anything that is new to the electrical engineers, but may be of value for those who are continually in contact with one phase or another of such propositions.

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* Meeting of Society, January 16, 1906.

† Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa,

The amount of power transmitted over a line is directly proportionate to the product of current and voltage. The amount of line loss is proportional to the square of the current and is, excepting for very high voltages, practically independent of the voltage. It is then evident that a high voltage is absolutely essential.

The extreme difficulty of obtaining a direct current high voltage, as well as utilizing it at the receiving end of the transmission line, has been considered by American engineers to practically rule it out. Some of the foreign engineers have succeeded in working a high voltage direct current system on a small scale, but the quality of success attained has not created any very great enthusiasm in favor of the direct current system. It is impracticable to operate direct current machines developing voltages much in excess of 1,000 volts—consequently, it is necessary to employ several machines in series, each developing from 500 to 1,000 volts. Each machine must be insulated from earth and from its prime mover for practically full line voltage. This insulation problem in itself is quite difficult and expensive. The machines can not be touched, excepting at very great risk, by the operators on account of their voltage to earth being so high. The number of units involved is excessive and, in general, are of such small size that poor efficiency is obtained.

No further reference will be made to the direct current system in what follows as it is the writer's opinion that it is not suited to long distance transmission for the reasons given above.

SECTION A.

The alternating current is suited to long distance transmission principally because of the ease with which the voltage can be changed from one value to another. It is possible to develop the power, in a low voltage generator, and then to raise the voltage, by using a transformer, to any value desired. A transformer is a very simple and rugged piece of electrical apparatus, without a moving part and having a very

high efficiency, 98½% being quite common in moderate sized units. In alternating current generators, it is possible to develop voltages as high as 20,000, as this class of machine does not have a commutation or collecting device in its high voltage circuit.

One of the early troubles, in the way of utilizing alternating currents for long distance transmission, was the lack of a suitable alternating current motor. The invention of the induction motor supplied this deficiency and then long distance transmission was an assured fact. The synchronous alternating current motor had been used prior to the discovery of the induction motor, but certain difficulties attending its starting made it hardly suited to the conditions.

The induction motor required for its operation two or three circuits, each of them being made up of an alternating current of the same frequency of alternation, but slightly different in phase. That is, each of the two or three currents reached its maximum value at a slightly different time from the others. If it is a two circuit current it would be known as a two phase current and the maximum values of the currents would be ¼ of a wave length apart, as shown in Fig. 1. The three circuit or three phase, as this arrangement is called, has its values attain a maximum at ⅓ of a wave length apart.

With currents displaced in phase it is possible, by properly connecting them to coils in a motor, to produce a magnetic field constant in intensity, but changing continuously in direction. Thus a rotating magnetic field results and any conductor placed in the field will tend to rotate with it. This is the elementary principle of the rotating field or induction motor, called two phase or three phase according to the number and phase relations of the currents for which it is designed.

Two or three phase currents are produced by having two or three separate windings on the armature of the generating dynamo. It is possible to change the number of phases by the employment of transformers. Thus two phase circuits

can be converted into three phase circuits and have the voltages changed in any desired amount at the same time; or a reciprocal arrangement is possible. In general, it can be stated that having given a two, or more, phase circuit, any number of phases can be obtained at any voltage through the employment of transformers. The frequency of the circuit is never altered by the employment of transformers.

The frequencies of alternation, that are commonly employed in American practice, has settled down to 25 and 60 cycles or complete waves per second. The 25 cycles are employed where the load on the system is mostly induction motors, or rotaries suppying direct current, or where single phase series motors are used. For incandescent and arc light-

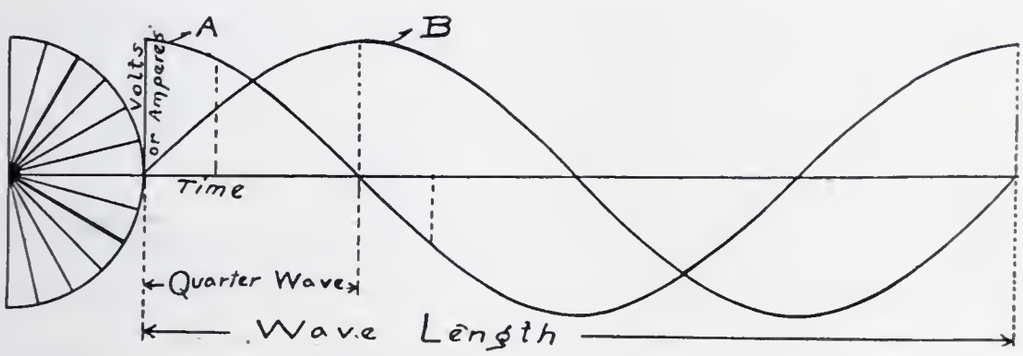

Figure 1.

ing the higher frequency is more suitable, and should be used on transmission circuits most of whose load is made up of that class of service.

Three phase currents are now almost universally used for long distance power transmission, though the new developments now being made, employing single phase circuits, may revolutionize this practice. Three phase circuits require but three wires and give a somewhat more efficient arrangement than the two phase circuits. Three phase alternators are most generally employed in developing electric power for transmission systems, this power being delivered to groups of single phase transformers arranged so as to properly raise the voltage without destroying the phase relations.

The connections most commonly employed are the star and delta, though, at times V. and T connections are used.

All of these arrangements take their name from the similarity of the diagramatic representations of these transformer connections to the above names, Fig. 2. The larger circuits represent the high voltage side while the small ones are the low voltage.

For general conditions the delta connection is to be preferred as it allows the greatest flexibility of operation. Transformers for star connection can be built somewhat more cheaply. The choice between the two systems will have to be made after due consideration of the relative importance of the two preceding points.

SECTION B.

The generating station, or power house, is located so as to be in most convenient relation to the prime source of power. As this is generally, in long distance transmission, a waterfall, but little choice of location is left. If a steam plant, more latitude is exercised in choosing the location and the customary questions of land values, relative location of plant to the district over which power is to be distributed, availability of water, transportation, facilities for coal, apparatus, etc., are the determining factors.

Generators. In all modern power stations, either steam or water power, the electric generators are direct connected to the prime movers, the size and number of units being determined by the amount and character of the load. There should generally be one spare unit ready should any of the others become disabled.

The several generators are generally worked in multiple, and as these machines are of the alternating current type it is necessary to synchronize them before placing them in parallel. The synchronizing consists in bringing the machines to the same frequency, which will be the same speed if of the same number of field poles, a close adjustment of voltage and an accurate adjustment of phase relation, that is, so that both machines reach their maximum voltage in the same

direction at the same instant. When running thus in parallel, if the governors on the prime movers have the same characteristics, the several machines will divide the load, as it varies, proportionally, and will run in as fixed a relation to each other as though connected by a system of gears.

Tendencies to hunt or pump on the part of either the prime movers or generators are quite nicely controlled by the employment of copper discs on the magnetic pole pieces, where they act as magnetic dampers tending to prevent any oscillation of one machine with regard to its neighbor.

The prime movers, as well as the dynamos proper, are under the control of the operator at the switchboard, who can start up or shut down any particlar unit without leaving his station at the control board.

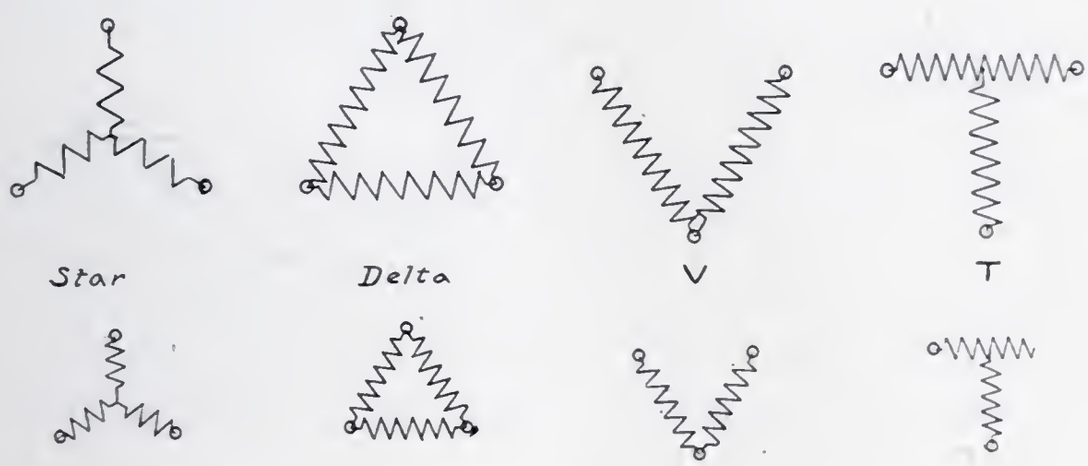

Figure 2.

The revolving field type of alternating current generators is practically the only kind being installed. The great advantages of taking current from its armature without sliding contacts, and the greater ease of insulation of a stationary part over a revolving one, have made this a standard type. This form has made possible the high voltage generators and machines of 10,000 to 13,000 volts, which are by no means rare. It is doubtless possible at the present time to build large sized machines capable of developing for service operation 20,000 volts and standing a 40,000 volt test for ½ a minute.

Transformers. In those plants operating a transmission line at voltages above 13,000 to 16,000, step up transformers are required.

The only function of these transformers is that of increasing the voltage and reducing the current to be transmitted in the same proportion. The transformer is a very perfect piece of electrical apparatus, consisting primarily of two coils of wire on an iron core and having no moving parts. It has a very high efficiency, 98½% being a fair value. Much better insulation can be obtained in a transformer than in a dynamo, use being made of the good insulating properties of mineral oils in which the transformers are generally immersed. It is thus possible to produce enormous voltages, far in excess of any that can be used practically on transmission lines as now constructed. One thousand volts per mile of distance to be covered is a figure that is fairly representative of present practice, though it is by no means exact.

Buses and switches. The power of the station is delivered from the high voltage terminals of the transformers to the high voltage bus bars of the station; from which it passes to the line. Power houses are usually provided with two or more sets of high voltage bus bars and the necessary interconnecting switches to allow any bank of transformers to operate on any bus bar and any bus bar to operate on any of the outgoing transmission lines. The interconnecting switches are generally oil immersed and electrically operated from the main switch board some distance away.

The low voltage side of the transformers has a similar arrangement of bus bars, switches, etc., allowing various combinations of generators and transformers to be made.

Switchboard. The switchboard is the heart of the whole plant. It is from the many instruments mounted thereon that the operator knows of the satisfactory operation of the plant. By close attention to the instruments the operator can tell more of the operating condition of the various machines than by looking at the machines. One of the most

recent installations has been constructed with the switchboard in another building apart from the generators and the operator controls the machines from the indications of the instruments alone. It is, of course, necessary to have oilers and wipers with the machines to see that all the bearings are properly cared for. The operator can, at any time, shift the load from any unit to another—can cause any generator not taking its proper proportion of load to "pick up" its part.

Automatic devices are, or can be, provided to cut out the various elements of the plant in case of excessive overloads or trouble.

Protective apparatus. Between the high voltage lines and bus bars the protective apparatus must be placed. This usually consists of a coil of wire, connected to the line side of which is a discharge gap or series of gaps leading to ground.

The function of this coil, and its gaps, is to afford protection to the apparatus in the station—such as the transformers, oil switch and high voltage bus bar insulation—against disturbances coming in on the lines due to lightning or faults on the lines; such as short circuits, grounds, etc.

The coil acts like a body of large mass to a mechanical force suddenly applied, and prevents the otherwise abrupt changes in voltage that would take place in the apparatus protected. The coil acts as a reflector and consequently has momentary increase in voltage on the line side, as it checks the incoming electrical surge, and this causes the discharge gaps to operate and dissipate the disturbing surge to ground.

The gaps are provided with some device, such as resistance in series and shunt relation, so as to prevent the dynamo currents continuing the discharge to ground after being started by the surge.

SECTION C.

The substations are located at points convenient to the place of ultimate utilization of the transmitted power. The character of the substation depends on the form in which it is desired to utilize the incoming power. Perhaps a brief dis-

cussion of three typical kinds will cover this point sufficiently.

First consider the case where it is desired to utilize all the power entering a substation for lighting—incandescent and arc. The station should then be provided with transformers for lowering the voltage. In such a plant, if the frequency is considered too low for satisfactory service, a frequency changer would have to be provided. A frequency changer consists of a motor receiving its power from the circuit of the transmission line, driving a generator supplying the desired frequency.

In either case power is generally distributed as single phase at a voltage sufficiently high to give economic distributing circuits. The arc light circuits are supplied from an arc light regulator, which is capable of supplying a constant current at a variable voltage, taking its power from a constant voltage source.

The use of the arc light regulator gives a more economical distribution to the lights spread over a considerable distance, permitting the operation of a variable number in series, and also eliminating the ballast resistance required in multiple connected arcs.

In some instances the voltage of the transmission circuit is too high to permit it coming into a city to a substation conveniently located for distribution. In such cases an additional substation is supplied, intermediate to the line and distributing station, at which the voltage is lowered to a safe value for bringing to the distributing station.

Voltages of 6,600 to 12,000 are used for this service, while 2,200 is the commonly adopted voltage for distribution from the distributing station. At the building where the power is to be used for lighting it must be passed through another transformer and have its voltage lowered to 110, at which it is used in the lamps. If a water power plant is supplying power for incandescent lighting some 30 or 40 miles away, the following transformations in voltage might reasonably be expected:—

Power developed at 2,200 volts, transformed to 30,000 or 40,000 volts, transmitted at this voltage; losing possibly 10%, and transformed to 6,600 volts at the 1st substation, to 2,200 volts at the distributing substation and again to 110 volts at the place of use. If the efficiency of the generator be taken at 94%, the first three transformers employed in the above series of four transformations be taken at 98%, the line at 90%, and the last transformer at 90%, 70% of the energy delivered by the water wheel to the generator will be available at the place of use for light. The above assumed efficiencies are not above what could reasonably be expected.

In addition to the above sets of transformers, the station equipment would consist of lightning protection, similar to that employed at the power house, and a switchboard providing means of controlling the distributing circuits.

The second case of a substation assumed will be that of one from which power only is to be supplied. Such being the case, the substation will be but a place for lowering the voltage to a value permissible for distributing and will, in general, not change the frequency or number of phases. It might be necessary, in some instances perhaps, to deliver part or all of the current as direct current.

This is accomplished by using a motor driving a direct current generator, or a composite of the two mounted on one frame and called a rotary. The same condition of voltage too high to permit of its entry into a city, as assumed in the first case, might arise, but would be treated in the same manner. The same kind of lightning protection and switchboard equipment as mentioned in the preceding case would be required, with, of course, some modification of details. The principal difference in the two kinds of substations, which lies only in the distributing one, is in the fact that in the first the power would be distributed and utilized as single phase; while in the last mentioned it would be three phase, as transmitted.

The third type of substation is that in which all the power is delivered from the substation as direct current for railway purposes. This station requires, as its equipment, the neces-

sary transformers to reduce the voltage to a value suitable for application to the rotaries or motor generators that must be used. If three phase rotaries are used the voltage must be 305 or 366, according to whether the direct current is 500 or 600 volts, as the ratio of voltage transformation of a rotary is rigidly fixed.

In general, rotaries will be used in preference to the motor generators on account of their greater efficiency, ability to stand overloads and less cost.

The same general statements regarding extra high voltages and the need of intermediate transformation, set forth in the two preceding types of substation, apply equally well in this case. There are also the same general requirements of lightning protection, switchboard equipment, etc.

This type of substation differs from the preceding in that it utilizes the polyphase powers without subdivision and has its entire output as direct current.

SECTION D.

The transmission line or lines, as it is common practice to have two or more independent lines, forms, of course, a very important part of the system. The development reached by the telegraph and telephone lines very naturally suggested that as a suitable manner of supporting the wires of the transmission system. It was soon discovered, however, that more substantial construction was required. The necessity of having continuous service, not interrupted by every little storm that passed, indicated the desirability of the best construction that could be supplied. The best practice now is that in which steel towers are used. These are set every 300 or 400 feet, the bases, in general, being carried on a concrete foundation.

The wires, which are bare, are given a large spacing. For 60,000 volts the wires should be six feet apart. The insulator supporting the line wires must be of sufficient size so that no electrical discharges will hold over their surface to the iron frame of the tower. This imposes a very severe con-

dition and is difficult to meet. The wire should not be nearer that 18 or 20 inches in a free air line to the cross arm supporting the insulator, and should have not less than 50 inches over which the discharge can reach the frame by creeping over the surface of the insulator, which is always in worse condition to resist the discharge than is the air by direct rupture. The changes of the insulator surface due to collections of dust, moisture, etc., always make it liable to break down unless ample allowance is made for that condition.

The material best suited to the construction of line insulators to meet conditions like the above, so far as present developments go, is porcelain. The porcelain used for that purpose is worked by the wet process and is so fired in the kilns as to thoroughly vitrify it, making it impervious to moisture. The insulators are made in several pieces, each completely closed at the top, and are carefully cemented together before being put on the line. Portland cement, sulphur and litharge and glycerine are three cements commonly employed for this purpose.

Large white insulators made up in this way have proven such an attractive target for hunters, as well as the small boy with his rifle, that it has been found necessary to color them so as to render them less conspicuous. A chocolate color glaze is now put on practically all porcelain line insulators for this reason alone.

Diversity of opinion exists as to the best kind of pin to employ, some believing in a metal pin and others in wood. Both kinds have points in their favor and the conditions of each individual case should govern in the decision as to which should be used.

In transmission at three phase, the present common practice, the wires are generally supported at the vertices of an equilateral triangle. This is an invariable practice at the higher voltages. Such an arrangement gives a symmetrical relation and prevents mutual interactions that would otherwise produce trouble. It is found necessary to change the relative positions of the individual wires, or transpose them

as it is called, to keep them balanced as regards their induced charges to earth, and to nullify inductive effects that they might otherwise have on adjacent circuits.

Where two transmission circuits are parallel to each other and separated by only 40 or 50 feet, it is necessary to transpose the two with special care as to each other.

With steel tower construction it is common practice to erect lightning arresters on each tower. These arresters are extended to a height of six or eight feet above the top wire and serve to prevent a direct stroke hitting the line within a certain radius. Some engineers advocate the stringing of an additional line wire, which is grounded at frequent intervals, as a means of lightning protection. This ground wire should be the top wire, though in some cases it is strung at the center of the triangle of wires, at the electrical neutral point.

There is a divergence of opinion as to the value of this ground wire as a protection, but it seems reasonably certain that it will afford considerable protection, not perfect immunity of course, if proper care is exercised in its installation to insure a good mechanical job with a ground at every pole.

A very essential part of every transmission system is a telephone line connecting the powerhouse with the substations and various patrol stations along the line. It is a comparatively simple matter to build such a line so that no difficulty will be experienced in talking over it when the transmission line is free from trouble. Up to the present, however, no satisfactory construction of a telephone line on the transmission line poles has been developed which will give telephone service regardless of the condition of the transmission line. In very important transmission systems a separate pole line some distance from the transmission line is built for the telephone service alone.

The right of way for a transmission system should be at least 100 feet wide and should be carefully trimmed of all trees that can fall on the line during storms.

In localities where large birds are liable to fly through or settle on the line the spacing between wires has to be increased above what would ordinarily be used to prevent them from short circuiting the line.

SECTION E.

The longest electrical transmission system at present operating is that of the California Gas & Electric Co. in California, where 200 horse power is transmitted over a distance of 220 miles. This company has been in successful operation for several years. Its power plant is located up in the mountains and its power is sold in San Francisco.

The Snoqualmie Falls plant, Fig. 3, is of interest principally from the novel location of its powerhouse, which is underground. The water is taken down a shaft in penstocks and passes through the wheels into the tailrace, which consists of a tunnel discharging into the gorge at the bottom of the fall. The same shaft that leads the water down is utilized as a cable way to bring the power up and after passing through transformers is sent to Seattle and Tacoma. There is nothing out of the ordinary about the machinery employed.

The Niagara Falls Power Plant, which is one of the pioneer plants, has a number of novel features. It is located about a mile above the falls, has its dynamos above ground and its waterwheels about 160 feet below the surface, but direct connected by long vertical shafting to the generators. The dynamos are of the vertical shaft type with revolving fields. The tail race consists of a tunnel ¾ of a mile long discharging into the gorge below the falls. This company, with their two plants running full load, have a capacity of 105,000 horsepower.

The Missouri River Power Co. is notable from the fact that it is the highest voltage plant operating. It has a line 63 miles long over which power is transmitted at 60,000 volts. This company is at the present time rearranging their equipment so as to operate at 70,000 volts.

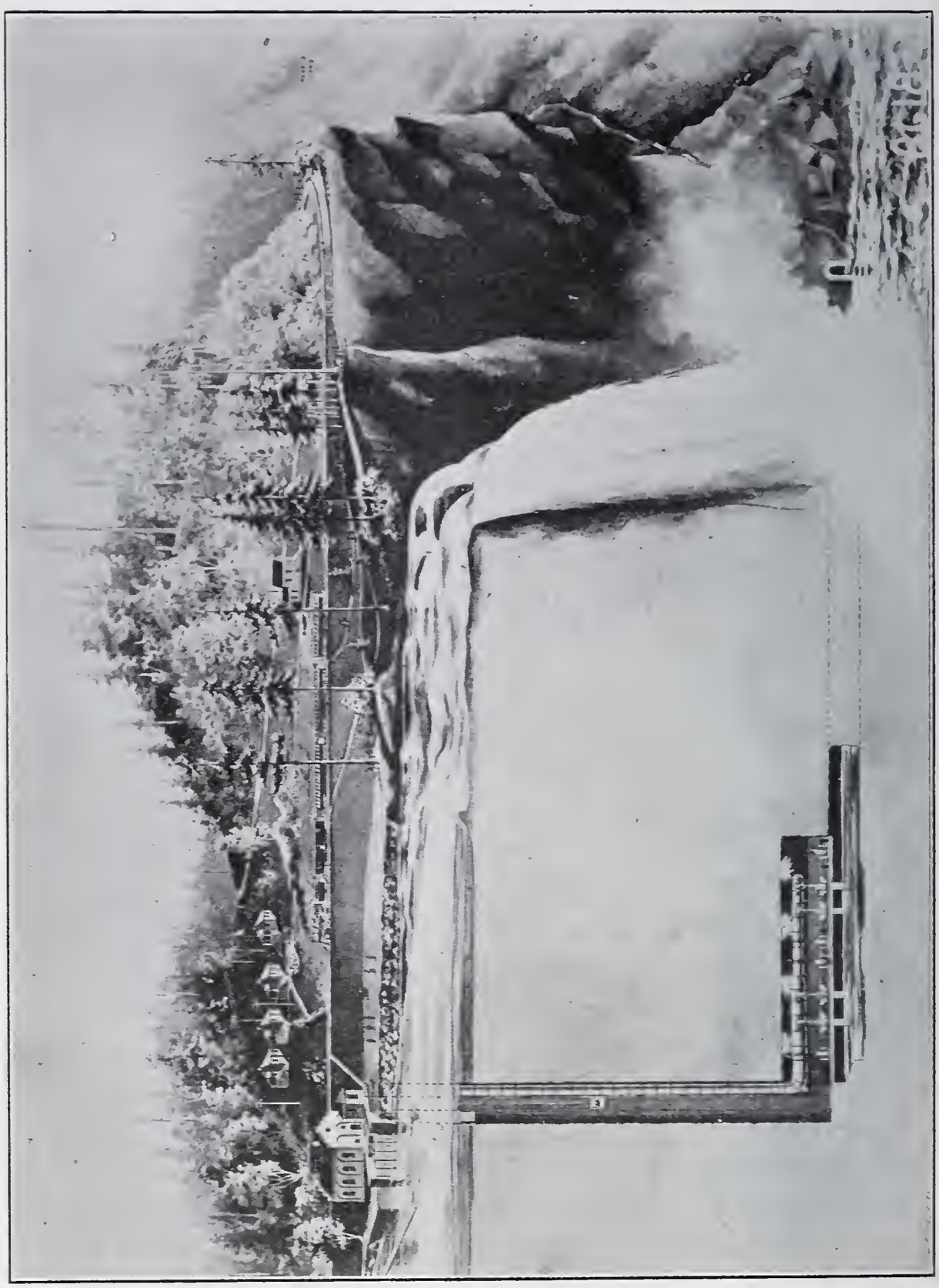

Fig. 3.

The Ontario Power Company, located on the Canadian side of Niagara Falls, is rapidly nearing completion. This plant is novel in a number of respects, chief among which is the separation of the switchboard and control of the generating machines from the same room, as is common practice, to a separate building about 600 feet away. The operators will be guided in their control entirely by the indications of the switchboard instruments. This plant is very carefully designed and will be, when completed, one of the finest in the world.

We, as Americans, take great pride in the fact that we excel the world in power transmission, but we will need to look to our laurels carefully if the present project in South Africa is carried to a conclusion. This contemplates the transmission of power from Zambesi Falls to Johannesburg, a distance of about 700 miles. It will of course be necessary to employ a voltage of approximately 150,000 or more, on a line carried part of the way through a wild and uninhabited country. Such a long line running North and South will always have very great climatic differences such as storms, etc., to contend with. From a strictly engineering point of view, it is a feasible project, and we, as engineers, will look anxiously forward to the time when it is put into operation.

DISCUSSION.

J. K. Lyons, Member—Is higher voltage used on the New York subway than is ordinarily used? My understanding is they have one large power plant which transmits to substations, then the voltage, I suppose, is further reduced, when it is used on the line.

C. F. Scott, Member—The large power houses in New York are practically all generating their current at high voltage; ten to eleven thousand volts is getting to be the standard. The current is conveyed by the cables to sub-stations, and for railway work it is first transformed to lower voltage by trans-

formers and is then converted into direct current by rotary converters. All of the large companies in New York use the same general scheme. The New York Central is installing a power plant which will supply alternating current at 11,000 volts to sub-stations.

G. E. Flanagan, Member—Regarding the current jumping across the insulators: Is the loss constantly occurring during the operation of the lines, and amounting to only a small amount, or is it of a momentary character, but of such large amount as to become a seriously disturbing factor?

C. F. Scott—The "leakage" may be of two classes: There may be slight leakage over the surface of the insulators, not enough to interfere with the operations. If in a telegraph system, where the amount of power involved is small, it might be a serious matter, but in power transmission it would not be a very large percentage of the total amount transmitted. On the other hand; there may be a break down over the insulator, which leads to an arc from the wire to the cross over, or to another wire. The current is usually so great as to cause at least momentary interruption to the service.

Wm. P. Flint, Member—I heard recently of a case of electrolysis in connection with a gas well which is located near a street car line. The current made its way into the casing at the surface, and down through the casing to the salt water stratum. It probably followed this salt water stratum to some other well, in order to get to the surface again. The destruction of the casing at the salt water stratum caused the discovery of this stray current, and after a new casing was put in, and insulated from the ground at the surface, a test was made with an Ammeter, and occasionally as much as sixteen amperes were found to have passed into the well.

A. E. Frost, Member—Is the direct current distribution likely to be superseded by the alternating single phase?

C. F. Scott—That is an unsettled question. We had direct current to deal with for a number of years, and in most

cases proper connections can be made so that the electrolosis is a minimum, or practically done away with.

G. M. Campbell, Member—Has Mr. Scott any figures on the cost of power at any of these large supply plants?

C. F. Scott—I believe the Niagara plant sell at something like $20 a horsepower a year to consumers taking large quantities. I believe that is about the minimum, and is for "24 hour" power.

Walther Riddle, Member—What proportion of the time do they shut down in the winter due to weather conditions, ice, etc?

C. F. Scott—Usually their shutdowns are of short duration. Their canals sometimes get filled with ice. At the Missouri River Power plant they told me that they had run 24 hours a day for a year, their loss of time was not over fifteen minutes due to troubles on the high tension line.

H. W. Fisher, Member—The manufacture of cable for very high voltages requires the greatest care in every particular.

A cable company cannot afford to take too great risks in supplying large quantities of cable for voltages much higher than have been operated through their cables before.

A short time ago an operating company wanted some non-leaded cables for station wiring to operate at 60,000 volts. These were to be placed on insulators and the conductors were to be sufficiently well insulated so that a person accidentally touching the cable would not receive a shock. We recommended the use of our varnished cloth with outside braid, and a test in water of this cable, made by the power company's engineer showed that 115,000 volts were required to break down the insulation. Such a cable is much stronger proportionately than high voltage insulators. In the former case, the thickness of insulation was less than half an inch, while that of the latter, often amounts to several inches.

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PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

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THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

*ERECTION METHODS FOR STRUCTURAL STEEL.

A TOPICAL DISCUSSION.

E. K. MORSE, Member—My experience in erecting has been almost exclusively that of bridge structures and masonry foundations. In fact I have not erected anything for fifteen or sixteen years, and I doubt whether you could offer inducement enough to get me back into the harness at the present time.

My first experience in erecting was in Punxsutawney, Pa., during the summer of 1876. I went there as a laborer, with a foreman sent from my brother's shop to erect a bridge. Soon after leaving Kittanning, two or three men we had picked up there asked what the hours were to be, and when I got a chance I inquired of the foreman what they meant. Up to that time my experience had been: What time do we get breakfast? What time do we get supper? In other words, daylight to dark, and the question of ten hours had never come into my experience. The labor market at that time, and up to 1897, was superior to anything we have any knowledge of at the present time. The wages for our best men were

* Meeting of Structural Section, February 27, 1906.

$2.50 a day. Any man who got $3.00 a day had to have a very good reason for it. In fact, I quit erection because the labor market went to $2.50 for 10 hours. The result was that the cost of erecting bridges, varied from 3/8 to 1 1/8 cents a pound. 1 1/8 cents would erect our heaviest bridges across navigable rivers, and in the seventies I erected a sixty foot span for sixty cents a foot. At that time the erection of buildings cost from 1/4 to 1/2 cents per pound. To-day the erection of bridges is from 1/2 cent up and the limit has not been reached. Buildings cost from 1/2 to 3/4 cents. I suppose some buildings cost one cent a pound to erect.

Until recent years no material was used in derricks other than wood, and it is my opinion to-day, that for any section, say not over thirty tons, with a boom radius of not over fifty feet, I would rather have a wooden derrick; because it is my experience that sooner or later the engineman is going to let the boom drop; especially if he is using a friction drum engine. If you have a steel, or better, an iron derrick throughout, and you let it drop, it generally goes to the shop. If a wooden boom drops and it cracks, or does not break clear in two, some planks are spiked or bolted on the side and the erection proceeds. A steel derrick is all right when you have over thirty tons. Take Blackwell's Island for instance where they are handling very heavy sections.

The question of engines is one that will vary with almost every foreman and every company, consequently, I have only the right to express my own opinion on that feature of erection. The best boiler that I ever used was a Lidgerwood. The best engine, with friction drum and "nigger head" up to four or six spool, was the Mundy. The most economcial engine I ever used for heavy erection was a Copeland & Bacon, 9 by 9, geared and reversible. The reason for that was you could hoist a section to the precise height and make quick connections. In the earlier days we did not have hoisting engines. We erected quicker than you do to-day, or did up to 1897, when we never thought of sending out a gang of men to erect a bridge or building with a hoisting engine. Why? Every-

thing was erected with crab gear, and if we had block and tackle there was no loafing. When a section was slung, every one went to the crab gear and went to work. Nowadays, after a member is slung everybody waits until the engine does the work. There is dead labor everytime. We were always able to erect a bridge, even for railroad construction where we were limited to fifty or sixty feet of a hoist, cheaper than you do with an engine. Where you are hoisting up 24 stories crab gear would be a very slow process, it is out of the question of course. But I do question if it would not be advisable, after a quick hoist is made from the street to the deck you are working on, to use crab gear for distributing and swinging the load into position. With a friction drum engine you are liable to jerk the load up and down, raising and lowering until you lose enough time to run the price of erection up very materially. As a rule, just so long as the engine is moving, just that long are a large percentage of the men idle. Furthermore, with limited means of hoisting with limited power, the foreman used his brain in working ahead, and that was one of the great secrets of Jake Peterson, one of Billy Baird's finest erectors. Jake would rig up in the morning what he was going to use in the evening, and there was never a delay. He would send out one or two men hours ahead to place a block and tackle, if it was nothing more than a six inch. They did not know what it was for, but sooner or later when it was required there was not a moment's delay. That is paramount when the question of economy comes into play.

To-day we have finer engines perhaps than we had then, but we have not the elegant timbers for our masts and booms. I thought nothing of going down to Alex. McClure's and asking him for a sixty foot stick, 12 by 12 or 18 by 18, white pine, without a knot, for a boom or a mast. When do you want it? This afternoon. It will cost you $2.00 a thousand more for extra delivery. What is the price to-day? You could not buy it to-day. You are to that extent handicapped. You have to use steel derricks to a great extent.

In ordinary construction, 100 to 125 rivets was considered

a fair day's drive for a riveting gang shifting its own scaffolding. Twenty years ago we used to thing nothing of driving 150 to 250 rivets on nice floor beam and stringer work, or heavy building work, but the men could not keep that up and shift their scaffold. The introduction of air riveters has been a great benefit, and simplicity of design has been a large factor. Fifteen or twenty years back we used to figure on the pound price, and we were often accused of "skinning" a structure. We figured our profit on what it weighed over the scale. That was hardly justifiable, and is now ignored by the best companies. It is no longer the question of pound price. Why? On account of our labor market. When anything went wrong when I was erecting bridges we did not wait to have it fixed; we fixed it; that was part of our business. We assumed that it was not going to go together right. If it did we were surprised. I know of only one structure, in my experience of bridge building, that went together without cutting and fitting. To-day if anything goes wrong there is a bill of extras at once. Now with all this improved machinery what is the condition of erection to-day? The labor market to-day, if I am properly informed, in this vicinity is fifty cents an hour on an eight hour basis, time and a half for extra time, double time for Sundays and holidays. What has been the effect of that on our modern erection? The cost of erection to-day is practically double what it was, and the time required is increased. With all our improvements we have doubled our cost and require, I think, at least fifty per cent more time, and on part of our construction fully double the time. Until we get our labor market and unions composed of good loyal citizens who respect and enjoy our institutions, I am afraid we shall continue to be handicapped in our construction.

Harry Bainbridge, Non-Member—The type of erection I have been connected with has been simple new work, and there has been nothing in the practice that is out of the ordinary. Ten or twelve years ago we lifted our work with derricks, and the old windlass or winch. In these latter days we use travellers and hoisting engines similar to such as have

been described by Mr. Morse. We do work quicker and cheaper I think, and I am surprised at Mr. Morse's remarks relative to the increased amount of time consumed in erection. But I am not in a position to make any comparison on the regular bridge or office building erection.

ROBERT A. CUMMINGS, Member—Mr. Morse has said he prefers the wooden derrick. Some structural engineers prefer the structural steel derrick. Can any one give us information upon that feature of the work?

E. W. PITTMAN, Member—I think steel derricks are cheaper now on account of the high quality of the timber required.

E. K. MORSE—We used Oregon pine exclusively in Australia. We could get timber that came from Puget Sound, 30 inch square and 60 feet long. I have seen 18 inch square and 120 feet long. We had only one trouble with it, and that was on account of the burning sun. The temperature used to get up to 140 degrees in the sun and the humidity was high. The Oregon timber would crack. You could not slide down it on account of the slivers, but it was tough, far ahead of our white pine.

The use of wire rope, to my mind is not so much the question of flexibility as of the amount of abuse it will stand. You can abuse a wire rope, you can drag it and use it chafing against iron or anything else and it will not cut like manilla.

T. J. WILKERSON, Member—You can get any size of Oregon fir up to 24 by 24 and from 125 to 150 feet long. I was very much surprised the first day I was in Portland, Oregon, to see a stick that was about 14 by 14 and over 150 feet long being hauled up the street. When used for bridge timber the same unit stresses are used as we use for oak in this country. It is very full of pitch, and in a warm country, where the pitch is liable to run out, it would probably sliver, but we did not have that trouble. We used a lot of 14 by 16, 65 fet long, and we purchased it for $7.00 to $18.00 a thousand,

but when you bring it here the freight is four times the cost of the timber.

T. S. Rice, Member—Speaking of Oregon pine, when I took the first bill of timber to a dealer in San Francisco I had it carefully sized up in 14, 16 and 18 foot lengths as we do in the East. The dealer told me that anything up to 24 by 24 and 60 feet long would be $16.00, but for large sizes he would charge a little "extra."

Robt. A. Cummings—We had occasion to have erected several guy derricks of Oregon fir, and while in ordinary operation one of those derricks broke off very suddenly near the top of the mast. It was found that the timber was very brashy, so much so that for our future derricks we have concluded to use yellow pine in preference to the Oregon fir. I would like to know if there are two or three grades of Oregon fir?

T. J. Wilkerson—Yes, but in Oregon they do not call that grade fir. They call it bull pine. They seldom use it, but use what is known as the Douglas fir.

Regarding the question of engines: It looks to me as if the company would send out the engines that would handle the structure most economically, but a small contractor would probably send out the engine he had. There is a great deal of money tied up in erection equipment. On the Williamette River Bridge for the city of Portland, Oregon, we had to take what we could get. We had a 9 by 14 engine, it was too heavy for the job, but at the same time we could not economically give that one up and buy a new one, for at the end of the work we would have the new one on our hands. When I was in the highway bridge business in the West we usually sent a man out with a box of tools, a crab and a coil of rope, and expected him to put up the bridge.

John L. Mullen, Non-Member—We have a Lidgerwood engine, modern stiff-legged derricks, the best kind of chain and the small equipment which we consider the best. I agree

with Mr. Morse that the Mundy engine ranks first although we are using the Lidgerwood. Not many years ago we used travellers on building construction, the Park Building in this city for instance. They do not use them on buildings to-day as they are too cumbersome. For example, I have just finished erecting a ten story building for the C. D. & P. T. Co. annex on Montour Way. The building is 55 by 80 feet and contained 632 tons of steel. We used a stiff legged derrick with a mast 33 feet high and a boom 68 feet long and the stiff legs of the derrick framed on 45 degrees. One day we finished setting one floor and moved the derrick up the next two floors, and were setting iron the same day; and working an eight hour day, too. That, I believe, a pretty quick move. I think cableguyed derricks were used in the erection of the Frick Building. They are not as quick as the stiff leg derrick for this reason: If you are going to use a cable guyed derrick on a building you cannot go out on some other person's property to guy your derrick, so you have to get some fastenings in the building you are erecting to anchor the cables to. The traveller is out of date. We have recently finished a building for Jones & Laughlin's that was 19 feet front and 90 feet deep. You would have a hard time using a slack wire derrick there, as we could not go on our neighbors property for anchorage. We handled that successfully with a stiff leg derrick.

We are handling a job at the Wabash Terminal now with an engine 6¼ by 8. We have another one on the same job 7 by 10. The size depends upon the character of the work. I would prefer an 8 by 10 on general work.

We have had considerable experience in the erection of cranes. When we have a heavy crane to erect we generally place the trolley in position and connect it electrically. We then make fast to the drum and make the drum hoist the crane into position. The crane is easily balanced by running the trolley in the required direction.

In 1904 we had an experience erecting a crane weighing 27½ tons for the Phillips Sheet & Tin Plate Co., at Clarks-

burg, W. Va. We shipped a crab, some lines and blocks, two pieces of 14 by 14 and a few planks. We began work there on a Friday morning and first made a pole. This was done by splicing the two pieces of 14 by 14 with a box splice. A box splice, I would explain, is made by putting the ends of the two sticks together and running your saw through so as to get a perfect bearing. Then planks are spiked or bolted on all four sides of the pole and you have a pole that is as strong as though it were solid. By Saturday evening the crane was up complete. The Master Mechanic of the plant doubted our ability to raise the crane with a spliced pole, but he changed his mind when he saw the crane hanging on the pole.

W. A. Swenk, Non-Member—We have had some experience with air machines for driving rivets. I do not think you get any cheaper rivets, nor do you get any better rivet than hand driven rivets. The air riveter forms a head on the rivet, but I do not think it fills up the hole as well as hand driving. We have riveting gangs to-day on the Wabash work driving rivets faster than I ever experienced with machine driven rivets in the field. We have had as low as 97 ¾ inch reamed rivets driven by four men with air. Of course, some gangs go as high as 400 and 450. We have a gang of riveters that drove 450 rivets yesterday by hand. In the erection of the ordinary office building I do not think it pays to put in an air plant for the small number of rivets that are to be driven.

E. W. Pittman—I have often heard the same argument as to hand driven and machine driven rivets. I have recently had some tests made with hand driven and air driven rivets in the same line. We cut them off and backed them out, and the hand driven rivets required about twice as many blows to back them out as the air driven rivets. It seems to me that is conclusive evidence that they are tighter, and therefore better upset.

A. Stucki, Member—That is simply a question of the size of the hammer and how the riveting is done. Generally

speaking, the more pressure and the less impact that is used, the better will be the rivet. This will put the hydraulic rivet at the head of the list. There the hole has to be filled completely, before the head can be formed. The steam driven rivet comes next, but as a rule, there is a slight crevice left in the centre, especially if the rivet is very long. In hand driven rivets you cannot expect the hole to be filled entirely, but by using a heavy hammer with moderate speed and striking the rivet straight the metal will upset for some distance, and if the rivet is not too long, a good job can be obtained. But if a light hammer with a quick blow is used, the impact will simply upset the end of the rivet, i. e. form the head. This is still more true if the rivet is not hit straight, which will cause the metal to catch at the edge and prevent its upsetting in the hole. These last remarks apply to air riveters also.

Of course we could not get along without air hammers nowadays, especially in structural work, where strength not tightness is essential.

Harry Bainbridge—We have had some work erected for us recently, and my foreman, a man of wide experience, told me that with the plant he has, using pneumatic tools, working the eight hour day and paying the union rate, he always counted that rivets cost about ten cents apiece, and the average number for a day would be 175. This is on fairly heavy work where at most there was only one movement of scaffolding.

E. W. Pittman—We have erected bridges where the rivets cost fifteen cents apiece. They nearly always run that on railroad bridge work, where you have to count on cutting out and redriving about 50% of them in order to get them tight enough to suit the inspector.

John L. Mullen—On bridge work I quite agree with Mr. Pittman that it depends on the inspector. We have for example the Pennsylvania Lines west of Pittsburgh. I think it is worth fifteen cents a rivet on that kind of work, but I have driven rivets on similar work, say in Alabama, at 7 cents a rivet.

E. K. Morse—I had four years' experience in field rivet heating, and I happen to know that in heating of steel and iron rivets there is a vast difference. Take our best steel and old fashioned wrought iron, and I will choose the wrought iron every day, and easily and safely heat the rivet thoroughly throughout. On the question of upsetting the shaft in the hole, it varies considerably with the weather. In zero weather and not any too good a hole the rivet will get blue before it is properly finished.

As regards the box splice it was the proper one to adopt for two reasons: One is it is the best splice, and the other is it is the cheapest splice and the quickest made. Almost any carpenter can saw square off but there are few carpenters that lap quarter or splice clear across perfectly. Moreover, where you have a timber cut off like a 14 by 14 you have a splendid bearing. If it is a very heavy load you ought to put a little piece of sheet metal between the abutting ends.

John L. Mullen—For derricks I prefer Oregon fir. About heating rivets that is covered altogether in the structural specifications. I have known specifications to read that when the rivet is heated the end must be dipped in water. That is done to prevent the end of the rivet from upsetting before the body of the rivet upsets. As to the pneumatic rivet as compared with the hand driven rivet, I agree with Mr. Swenk that a good hand driven rivet is equally as good if not better than a rivet driven by impact. I agree also with Mr. Stucki that the rivet driven with a hydraulic machine is best of all.

C. H. Umstead, Member—I had occasion to compare steel and iron rivets not long ago, where we had to cut out rivets on two jobs that were near together. The steel rivets were cut out with one or two blows, but it took about half an hour to cut out a wrought iron rivet.

John L. Mullen—Mr. Pittman spoke of a test between hand driven and air driven rivets. We have just finished cutting out about 6,000 rivets on the Wabash terminal that were

air driven rivets, and we never had any trouble at all backing them out.

E. W. PITTMAN—In the tests I spoke of; the rivets were driven at the shop where they did nothing but rivet, so they were pretty good rivets. It seems that they drove better hand rivets there than they did air rivets. But the conditions were the same.

A. STUCKI—What is the best practice, to leave the collar on or to cut the collar off? To my mind if I see a collar all around I know I have a good rivet. If that collar is not there I do not know what I have got.

E. K. MORSE—That depends altogether on whether you have more material than is necessary to fill the hole. There is always danger in heating a rivet of burning it. A wrought iron rivet you heat until it will spark. In that case you always have about an eighth to a quarter of an inch more material. I do not care particularly about the looks of the rivet so it is filled inside. When you work around until you cut off the collar you are apt to be cutting into your metal before you know it.

I question if there is any one that can give me a section that I cannot make the rivets loose by using a little linseed or crude oil. That will loosen the scale that is on all rivets. You cannot get a rivet into a hole without scale. You cannot heat a piece of metal without scale. The way to take that off is to put oil in. Put on a hose and the next morning it will be rusted and tight.

F. R. JENNINGS, Member—With regard to the point raised about cutting the collar off the rivet. I have driven a large number of rivets both in the shop and in the field and was always required to cut the collar off. I do not think that is necessary on structural work, but when you are riveting a gas or steam tight job it is better as this tends to caulk the rivet head tight against the plate. A disadvantage of cutting the collar off is that in order to save the labor necessary to remove

the collar the length of the rivet has to be close to that necessary to form a perfect head, and this does not allow enough variation for the different diameters of holes due to too much reaming or drifting.

F. M. Bowman, Member—I believe it is possible to loosen rivets with the air blast. Rivets are frequently loosened by careless and inexperienced inspectors by too much tapping of the rivet. I would like to say here that some bridge companies make a practice of doing the reaming of field holes for railroad bridge work in the field. The Pennsylvania Lines West, the New York Central and a great many other roads require field holes to be sub-punched and jig reamed in the shop. Where this is required, rather than do the jig reaming in the shop the work is shipped unreamed to the field and all reaming of the field holes is done there, reaming out generally $\frac{3}{16}$ inch. This gives much better holes than any jig reaming or setting up in the shop, because material will not come together exactly the same in the field as it did in the shop, and it may surprise you to learn that the cost of the riveting is so much reduced in the field, on account of the excellent holes, as to make up for the cost of the field reaming.

As to the cost of hand or air driven rivets, and which to use for any particular job, this depends upon the size and nature of the job and how many rivets you have at one connection. Take railroad work, where you usually have a great many rivets in each connection, it certainly pays to put in a good air plant and with it you get the best possible rivets.

With regard to the question of long rivets, I do not see any objection to dropping the end of such a rivet in water to cool it before driving. I believe the tendency today is to make the head of the rivet too large. There is no advantage theoretically in a large rivet head, and in driving the power is used in forming the head instead of in filling the hole, especially with long rivets; this is true to such an extent that we find it much more difficult to cut out a small headed rivet than a large headed one. In other words the smaller headed rivet is much tighter and stronger than the larger.

I might go back a little to the subject of travelers and crabs to say that every job has an equipment that is suitable for that job. If you are erecting a very small building it would be unnecessary to send an engine, a crab would be most economical. The advantage of a steel traveler over one built of wood is that you can use it over and over again. We have a steel traveler with which we have put up ten large buildings and we are still using it. A steel traveler, of course, would not be used except on comparatively large buildings.

As to the cost of erection, it is my opinion that erection to-day costs on an average nearly twice what it used to at the time Mr. Morse spoke of. A building that would be put up ten years ago at $7.00 a ton would cost not less than $12.00 a ton to-day, where the erection takes place in a district like Pittsburgh. Of course, in Alabama we can get labor at less rates, and I readily understand that the cost of driving rivets would not exceed seven cents, as stated by Mr. Mullen, and in fact rivets have been driven for as low as four cents on an average for large jobs. At the same time I think fifteen cents a rivet for railroad work is a low cost, especially if the inspection is rigid and cranky. It is a fact that frequently 50% of the field rivets and sometimes more are cut out by the inspectors and must be re-driven.

E. K. Morse—I had occasion on the Monongahela Connecting R. R. bridge across the Monongahela River to go over it once a month and cut out rivets in the connecting stringers and beams. They would get loose and the heads would fly off, and we made a practice of going over it once a month and taking out from 50 to 200 rivets. One day I asked the foreman to put in some hexagonal bolts. We found they gave satisfaction so we cut out all the rivets and put in bolts and that ended the trouble. The reason is this: You can put tension on a bolt head, but you are not allowed to figure tension on a rivet head.

Frank McEwen, Member—What is the longest rivet that it is practicable to drive? Some specifications require the use of bolts beyond a certain length.

F. M. Bowman—I think six times the diameter of the rivet is the usual maximum specification, but we have driven rivets that were 6⅛ inches long and 1 inch in diameter. On plate girder work where you put in stiffeners, you have perhaps an inch more length at the ends of the stiffeners than you have ordinarily. That is one place where you have trouble in getting rivets tight, and the rivets ought to fill the hole or you will not get the action you are supposed to get for carrying strains. I think a bolt will fill the holes properly, but the rivet is usually preferred, I suppose the reason is that the bolt is generally a sixteenth less in diameter than the hole and there would then be some play. I certainly would prefer a good bolt in the case mentioned.

E. K. Morse—The bolts I referred to were finished machine bolts, not the ordinary erecting bolt.

T. J. Wilkerson—The American Railway Engineers & Maintenance of Way Association specification is the only one I remember seeing which specifies that the rivet can be taken at its full value as long as the grip does not exceed four times the diameter, and from that up decreasing it 1% for each addiitonal $\frac{1}{16}$ inch grip. That is, a ⅞ inch rivet would be good for 3½ inches grip without decreasing its value.

A. Stucki—If you go to the trouble of reaming the holes in the field, of using bolts and of finishing the same, I would say, go one step further and use a taper bolt, it can be turned just as cheaply and accurately to a standard taper, ream to let the bolt enter within about ⅛ inch, then drive the bolt home and you will have a first class job.

*BRIDGES.

†WILLIS WHITED.
Member.

It is proposed this evening to discuss a few points in bridge designing.

We will first take up the column formula. To my mind, the most rational treatment of this subject would be to ascertain what are the greatest deviations from the ideal column that may be looked for, under the existing conditions of workmanship and inspection.

The ideal column is perfectly homogeneous, perfectly straight, and the load is applied exactly at the center of gravity. In practice none of these conditions obtain. Tests of full-sized members are of little value; First, because the experimenter has no means of knowing beforehand whether the maximum practical variations from ideal conditions all obtain in any given case; Second, because a long column will ordinarily fail whenever the elastic limit is passed in any portion of it; by reason of the well-known fact that few, if any, of the formulas for resistance to bending apply to steel without important changes after the elastic limit has been passed in any portion of the member. What is wanted, as I understand it, is to so design the column that, under the given load, no fiber would be strained beyond the specified limit, if the column were imperfect by the greatest practical amount in every respect.

It is a general rule among shop inspectors to reject all compression members that are not straight within a quarter of an inch. If the member is pin-connected, the pin holes will be within about an eighth of an inch of the axis of the

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† Department of Public Works, Pittsburgh, Pa.

member. If the connections are riveted, the connecting rivets may not be quite symmetrical, but if the work is well detailed, the rivets will generally be capable of transmitting the stress to the axis of the member. During shipment and erection accidents may happen which will spring the column somewhat more, but it is probably safe to say that no reasonably competent inspector would pass a column which was not straight within three quarters of an inch after erection. He would be fully as likely to notice a greater deviation than that on a very long column as on a comparatively short one. We may, therefore, consider that ample allowance has been made, if we assume that a column thirty feet long is straight within one inch, columns less than ten feet long will generally be curved more than that in proportion, but members so short as that are seldom used, except in lattice girders and for lateral bracing, in which cases they are rigidly fixed at both ends. In point of fact, nearly all bridge members are more or less securely fixed at one or both ends, perhaps by riveted connection to lateral bracing or floor system, or perhaps by friction on the pins, or in other ways. When a bridge post is packed in with other members on the same pin, they will, I think, rust together within a year or two so firmly that they might safely be considered as having fixed ends.

If a slightly curved column be subjected to a compressive stress, its curvature will be increased an amount determined by four factors: (1) the magnitude of the stress; (2) the amount of its initial curvature; (3) the form of its initial curve; and (4) the modulus of elasticity of the material on the concave and on the convex sides of the neutral axis. If it is of steel and composed of a single piece, or if, as is often the case with web posts of bridges, every piece of which is built symmetrical about the axis of its least moment of inertia, we could safely assume that the modulus of elasticity is the same on both sides of the neutral axis. But if it is of iron, or built up of smaller sections, the modulus of elasticity might be smaller on the concave than on the convex side, in which case the deflection under load would be greater

than if the modulus were the same throughout the column. If we assume the modulus to be 28,000,000 on the concave side and 30,000,000 on the convex side we will doubtless be on the safe side, making all necessary allowance for internal strains due to driving rivets, straightening the material, etc.

The deflection due to the load will vary considerably, according to the form of the initial curve. If the curvature is all close to the ends, the deflection will be notably greater than if the curvature were all near the middle. On the other hand no inspector would accept a column with a short kink anywhere in its length, so that it is safe to say that the curve of the neutral axis of a column will never differ very widely from a parabola. Some of the mathematicians connected with this Society can, from these data, more or less modified perhaps, develop a formula which, in my opinion, will be as nearly rational as any that has yet been proposed. If the mathematical expressions developed are too cumbersome for practical use, a table can be prepared giving the ratio between the mean stress and the maximum stress in the fibers of a column of different values of $\frac{l}{r}$, and from this a curve can be constructed which will give results amply accurate for any practical purpose.

It is a well established fact in chemistry that iron will not rust in a basic medium. Cement and lime are quite strongly basic, therefore, if steel work is completely covered with a layer of cement mortar rich enough to exclude moisture, it positively cannot rust.

Iron rust is a hydrated oxide of iron and has about four times as much volume as the iron from which it is made. The expansion which occurs in rusting acts with great force, sufficient, in fact, to break large stones if the steel is bedded in them. So, if steel work is surrounded with mortar or concrete, if by any cause rusting should occur, it would be revealed by cracks in the concrete before it had proceeded to anything like a dangerous extent. It is seldom practicable to protect any considerable proportion of the steelwork of a bridge with lime or cement. Recourse must be had to paint.

Bridge painting should be done by competent men working by the day. Paint will not strick to greasy steel. If it is applied over rust, dirt, or mill scale, they come off and bring the paint with them. Therefore the steel must be thoroughly cleaned, and the paint well worked into all the minute depressions in the metal, so as to thoroughly expel air, mosture and carbonic acid, all of which are necessary to produce rust. Almost any other acid, or certain salts, such as ammonium or sodium chloride, will act the same as carbonic acid, and perhaps more rapidly, but they are seldom present.

The almost universal vehicle for paint is linseed oil. Some others have been used, but I have been unable to obtain much reliable information about them. Their composition is secret and no definite information is forthcoming as to their properties. Linseed oil hardens by oxidation. If it is applied pure the oxidation makes it somewhat porous. Pure raw oil hardens slowly, and is not a very efficient covering on account of its porosity, but paint adheres well to it. Boiled oil contains a drier. The best driers are certain compounds containing manganese dioxide, lead oxide, or some other inert substance that parts with its oxygen readily. This oxydizes and hardens the oil. The coating is not so porous as raw oil, but it is not so tough and its brittleness extends to subsequent coats of paint which may be applied. On account of its porosity, as well as for other reasons, linseed oil requires a pigment mixed with it.

For priming, one of the best pigments is red lead. It is an efficient drier itself and can be mixed with raw oil without other drier. It seems to give up its oxygen to the oil, and to absorb oxygen from the air to replace it, so that it does not fade. It turns dark when exposed to sulphurous gases and makes the oil somewhat brittle, so it is not good for an outside coat, but it adheres very closely to the metal and makes an excellent foundation for other paints. The principal objections to it are the tendency to settle in the paint pot and to run when applied to a vertical surface. These difficulties are more or less successfully overcome by some manufacturers,

but their methods are secret and I have no reliable information as to their value. I am informed that a moderate admixture of lamp-black obviates the difficulty to a large extent.

Graphite is an excellent pigment. It is absolutely inert and unaffected by gases and other chemicals. It has great covering power and good body, that is, it is very opaque. It requires a drier as it contains no oxygen. It contains a considerable proportion of impurities, but they, so far as I know, are harmless. It is also rather cheap.

White lead has been used for centuries and is an excellent pigment. It settles more rapidly than graphite, but not so rapidly as red lead. It requires a certain amount of drier, but not so much as graphite. It becomes chalky and rubs off in time and turns dark on exposure to sulfurous gases. It has great covering power and body.

Lead sulfate is used considerably. This is not affected by sulfurous gases, but it has less body than white lead.

White zinc is a good pigment, but if used pure, is liable to peel off. It is usually mixed with white lead in about the proportion of three parts of white lead to two parts of white zinc. It is not affected by sulfurous gases.

Lampblack is a fine pigment. It resembles graphite, but is finer, lighter, more opaque and more expensive.

Chrome yellow is used with other pigments, but seldom alone. It is much more opaque than yellow ochre, but like other lead pigments turns dark on exposure to sulfurous gases. It should not be mixed with any pigment that is a sulfide for the same reason. It is rather expensive.

Iron oxide is a very cheap paint and a good one if carefully made and of good material. It does not settle, run, nor fade to any troublesome extent, and is not affected by sulfurous gases.

Turkey red, yellow, ochre, umber, sienna, venetian red and some others are composed mostly of iron oxide with a large admixture of clay, sand, and other earthy matter. They have much the same properties as the iron oxide paint mentioned above. They are rather inferior in opacity.

There are many other pigments used, but most of them are rather expensive and are employed principally for tinting other colors.

Driers must be used, to a greater or less extent, with all pigments except red lead, but use as little as practicable. Too much drier makes the paint brittle. Benzine and turpentine are not properly driers at all, they are only volatile diluents and should not be used on outside work. They tend to disintegrate the paint.

The most effective method for cleaning steel preparatory to painting is by the sand blast. In the shop or yard it is little if any more expensive than hand cleaning, but is more expensive on bridges after erection. It cannot be used on city bridges above the roadway. It removes, to a considerable extent, the minute depressions that are difficult to fill in painting. Steel cleaned by sand blast must be painted immediately, because it rusts very quickly.

The life of a steel structure is comparatively brief in many places, for example, where exposed to salt spray, sulphurous or other acid gases from the smoke stacks of locomotives. In these places paint is not an adequate protection. The ore dust emitted from some of the blast furnaces in this vicinity seems to corrode steel very rapidly. Whether this is due to sulfurous acid or to oxygen occluded in the dust or to other causes, I am not prepared to say, but the fact is beyond dispute.

It is pretty well established that steel rusts more rapidly than iron. It was suggested by a prominent chemist that that might be due to the manganese in the steel. If so it might be due to some catalytic action that manganese may take in the case.

As stated above, if steel is completely covered with cement or lime it cannot rust. That is one reason for the great popularity of reinforced concrete. Another reason may be suggested as follows: Ordinary structural steel costs, erected, in the neighborhood of $500 per cubic yard. Concrete costs between $5 and $10 per cubic yard. In reinforced

concrete structures not far from \$8, or $\frac{1}{160}$ as much as steel. Steel can be used in compression at about 12,000 pounds per sq. in., concrete can be used at about 600 pounds per sq. in., or $\frac{1}{20}$ the value of steel, so that steel costs about three times as much as concrete as a compression member. In tension, on the contrary, steel will withstand a working tensile stress of about 13,000 pounds per sq. in., while concrete must be restricted to about 50 pounds per sq. in. or $\frac{1}{260}$ as much as steel. It therefore costs about four times as much as steel. Now if we can build a structure employing steel in tension and concrete in compression, we shall obtain equal strength at about one half the cost. There is a further advantage in the use of reinforced concrete. Most of the steel employed is in the form of plain round bars which cost only about one half as much per pound erected as structural steel. There are practical difficulties that make it impossible to realize all this advantage in economy, but it is easily seen that an important economy is obtained. There is the further advantage that reinforced concrete, if well made, is vastly more durable than steel. Of course it is not adapted to all situations. It is much cheaper for arches than either stone or steel, within certain limits as to length of span. It makes excellent viaducts in either arches or what might be called cellular construction. This consists of a wall, the full height of the viaduct on each side, joined together at frequent intervals by cross walls and floored over with reinforced concrete slabs. No filling is required, and the wall can be of very moderate thickness. This will be found a very cheap and durable form of viaduct. The side walls can be faced with brick or stone if desired, and it is not always necessary to carry the partition walls down to the ground, but they must be designed to give ample stability.

DISCUSSION.

THOS. H. JOHNSON, Member—I gather from Mr. Whited's remarks, he was speaking only of the fibre stress and flexure of the column. I did not hear anything said about the combined stresses which are partly due to flexure and partly to direct compression. There is no formula in existence, that I know of, that enables you to calculate the fibre stress in a column, due to the combined action of both stresses. In that connection Mr. Whited spoke of confining his tests only to the elastic limit.

The relation between the elastic limit and the ultimate increases with the length ratio as we approach that part of the curve where Euler's equation applies, that is to say, the elastic and ultimate strength approach each other, and finally we reach a length ratio beyond which the ultimate strength is less than the elastic limit. In other words, the bent column ceases to offer added resistance to increased loads, before the fibre stress has reached the elastic limit.

If you have a force acting downward on the top of the column, and the column is resisting that force, partly by compression and partly by bending, you cannot use the total load to calculate both forms of fibre stress. You must find some basis for dividing that load between the two kinds of reaction. That is what we have no means of doing. No formula has ever been devised to meet that. Perhaps I might make that clearer. Compression shortens the column, just as it shortens a helical spring, and in proportion as the shortening increases, the resistance increases. The same way with the flexure. As flexure increases, resistance increases. Thus there are two forces opposing the imposed force. Now the sum of those two forces must equal the imposed force. You cannot have each separately equal to it.

A. STUCKI, Member—Referring to the question of columns, Mr. Whited spoke about the two extreme cases, one where all the offset is at the top, and the other where the offset becomes a maximum at the centre. Leaving the deflection of such a small overhang out of the question, it will be

noticed that the two extreme cases both call for the same maximum cross section. The only difference is, that in the first case this section is already needed at the top, while in the other case not before the centre is reached, and since the column is of a uniform section anyhow, the two extreme positions mentioned do not affect the strength in the least, but simply cause the dangerous point to shift.

K. A. Muellenhoff, Member—In a certain mill in Germany, we found the cleaning of steel, by a sand blast, to cost about the same as hand work, but hand work is a good deal cheaper there. But we had to stop its use as it weakened the rivet heads. For first class work, as railroad bridges, the following method of cleaning is generally specified now: After the parts have been assembled, the whole member, e. g. a plate girder, is placed in a tank filled with a thin solution of hydrochloric or sulfuric acid. This removes all rust and scale and gives a perfectly clean metallic surface. As soon as this is done, the piece is lifted out, rinsed with water from a hose, and in order to be sure that all the acid is neutralized, it is put in a second tank filled with limewater and left there for a couple of minutes. Then it is taken out, rinsed again, and put into a third tank filled with hot water. As soon as it is taken from that it is perfectly clean and becomes dry in a very few minutes. Then the first coat of paint is applied, consisting of linseed oil with 10% of zinc-white. Before shipment it gets a coat of red lead. A second coat of red lead is given after erection, which is protected by at least two coats of some other paint. This process is a little expensive, but it gives excellent results.

When I first came to this country, I was amazed at the great number of column formulas in use here. In Germany we use, either Euler's formula, or Rankin's formula. I tried to get an idea of the reliability of the different formulas, by applying the method of least squares to the results of a great number of tests made by Tetmayer at Zurich, and to some tests made in this country. I have not finished all the calculations, but as far as I can see now, for columns whose value of

$\frac{l}{r}$ exceeds 115, Euler's formula is the only good one. Even if you determine the constants in Rankin's formula by the method of least squares it gives far greater medium errors. For shorter lengths the formulas of Prof. J. B. Johnson and of our member Mr. Thos. H. Johnson, give equally good results (with slightly changed constants.)

The medium error amounts to about 7.9% for the "straight line" formula of Mr. Thos. H. Johnson, to 7.85% for the "parabolic" formula of Prof. J. B. Johnson, and to 8.2% for Euler's formula. For Rankin's formula it amounts to 11.35%, but with much changed constants. The original constants are wrong and I think this formula should not be used.

Thos. H. Johnson—I have very little sympathy with the use of sand blast for cleaning metal structures. You cannot do it out of doors, particularly in wet weather, because the rust will follow right behind the sand blast, and the painters must be working right in the cloud of dust if you are going to keep it from rusting. And then it is very apt to work under the rivet heads and loosen the rivets.

E. K. Morse, Member—I am convinced, from observation of my own work, that we have come to a point in the use of steel in exposed places, such as bridges and structures exposed to the air and climatic conditions of this latitude, where we must carefully consider its use. I am satisfied that steel, as now manufactured and used, even with careful attention to painting, will not give reasonable satisfaction in exposed positions, but is entirely satisfactory when protected from the weather. I had occasion, last summer, to pass judgment on some of my own work that had been in existence about eight years. On many sections there were places where the metal had rusted entirely away. This was especially noticeable in all horizontal legs of angles, plates, etc., where the moisture was held in suspense. The worst places were those over and near the railroads, where they got the fumes from the locomotives. No doubt the sulfur was the cause of that.

I am satisfied that we will either have to return to wrought iron, or we will have to use some combination in the manufacture of steel. It is possible that the introduction of a small percentage of nickel in wrought iron would increase the elastic limit sufficiently to meet the demands of the engineer for a material with a high elastic limit.

We have made tremendous strides in this country in our frame structures, but we have made but little advancement in our method of floor system. That has led me to use and adopt slag sand for a cushion on which to place the ordinary surface ties, and requires a somewhat different arrangement of the track stringers decked with buckle plates on which at least one foot of sand is spread. You take a floor system that has some elasticity in it, and you have eliminated the great factor of impact. A load going over that kind of a floor is very much easier on a bridge than it would be going over the solid floor.

Thos. H. Johnson—I think the explanation of the horizontal members rusting is very simple. The dust and dirt which collect on them is not cleaned off, and in the vicinity of a railroad cinders gather amongst it, and all that stuff lying there acts by capillary attraction and takes moisture in to the surface of the metal on top of the paint, and it gets in to the metal afterwards.

H. S. Prichard, Non-Member—I first gave serious consideration to the question of the effect of impact on structures many years since, at a time when I was connected with the New Jersey Steel & Iron Company. While endeavoring to verify the various formulas contained in their hand-book, I came across one of formidable appearance, which provided for the effect of impact on beams. The struggle with this formula held me for a while, but not long afterwards our concern heard a cry for help from some architects, who had been called upon to advise as to the safety of a warehouse in which the workmen who loaded the building were in the habit of dropping boxes full of iron and steel plates upon the floors.

We went to their rescue; had we not a formula for impact, and had I not verified it? We found, from analysis, that those floor beams, according to our formula, must have utterly failed the first time the load was dropped on them. We put the formula carefully back in its place in the book, on page 39 (where it is still resting) and then went seriously to work on the problem. The floor was cleared for test, the loads were dropped experimentally and the effect on the beams determined from their deflection. We found that the potential energy produced by dropping the loads, instead of going into the beams and causing them to vibrate until the energy was transmitted to the beams' surroundings, took a short cut and went to the surroundings direct, shook up the box and its contents, jarred and dented the floor, and was dissipated in other ways; only a fraction of it reaching the beam. This experience lessened the respect which I had heretofore felt for impact formula based on purely theoretical conditions, and it convinced me that the way to determine the effect of impact on structures, under given conditions of loading, is to measure the deformation of structures under such conditions.

In 1895 the New Jersey Steel & Iron Company, of which I was then the Engineer, after examining all the data readily available on the effect of impact and vibration on railway bridges, inserted in their specifications the following provision for impact and vibration:—

$$I = \frac{L + D}{L}$$

In the above equation I = effect of impact and vibration; L = Live Load and D = Dead Load. This formula was adopted by Mr. J. W. Schaub in his specifications which appeared in a paper before the Western Society of Engineers, October, 1900, and was given by Mr. E. Herbert Stone in a paper on the "Determination of the Safe Working Stress," delivered before the American Society of Civil Engineers, July, 1898. It is also mentioned in the Historical Sketch on the Development of the American Bridge Specifications, pub-

lished by the American Railways Engineering and Maintenance of Way Association, April, 1905.

The designing of columns is a matter in which I have always taken a considerable interest. It is a curious fact that the theoretically correct formula for columns under ideal conditions is by far the oldest one; having been published by the fine old scientist, Euler, in the early part of the 18th century. The conditions he assumed are approximately realized at times in the laboratory, but nowhere else. One of the best investigations of columns as they are was given by Professor Fidler in a paper before the Institution of Civil Engineers in 1886. The formula he obtained is too complicated to use in the ordinary way, but he determined its results for a complete series of ratios of length to radius of gyration, and plotted the resulting curve, together with the results of a great many experiments; the agreement of which with his curve was very close. He developed the formula on the supposition that material is not entirely homogeneous, and that, consequently, the center of gravity of the area of the cross section is really somewhat eccentric with regard to the center of resistance. In other words, he assumed that every column is liable to bending stresses from eccentric loading, even when seemingly loaded in the center of resistance. Like all column formula that have been developed from a correct basis, the results for the failure loads of long columns approach closely to those given by Euler's formula. There is, however, a decided difference between the action of long columns under ideal conditions and their action under actual conditions of practice, even though there is not much difference in the loads under which the columns would fail. Under ideal conditions a column would have no deflection until the failure load was reached, while under actual conditions, which involve eccentricity, a column will deflect from the start and increase, as the load is increased, until failure.

On the numerous empirical formulas which have been published, I consider that the parabolic form proposed by Pro-

fessor J. B. Johnson is by far the best. His general formula is as follows:—

$$\left.\begin{array}{c}\text{Greatest load per}\\ \text{square inch}\end{array}\right\} = \text{Elastic Limit} - X\left(\frac{L}{R}\right)^2$$

$$\frac{L}{R} = \frac{\text{Length}}{\text{Radius of Gyration.}}$$

In this formula X is to be given such a value as will make the curve tangent to Euler's. Professor Johnson only advocates this formula for short columns, in which the value for the "greatest load" is less than would be obtained from Euler's formula. In thus limiting the use of the formula, I believe he has made a mistake. The discussion as to the ultimate strength of long columns is purely academic, as no engineer in his senses would think of permitting long columns in any structure, for the design of which he was responsible. In fact, it is the universal practice to arbitrarily limit the length of columns. If the parabolic formula is used without limitations, it will naturally prohibit the use of long columns, by giving zero as the greatest load permissible for columns beyond a reasonable length.

I have listened with great interest to the discussion regarding the protection of exposed iron and steel from rust, and I am convinced that the matter is one which requires earnest consideration. For the skeleton frame of tall buildings, it is wise to minimize the danger of exposure by placing the columns just inside the building, instead of building them in the outside walls. The wall girders are then supported by the cantilever ends of girders arranged in pairs, which straddle the columns. This construction was first proposed, I believe, by George B. Post, architect, New York. Under this arrangement, not only is the column protected from moisture which the walls may absorb during heavy rains, but it is accessible for examination at any time, without disturbing anything but the immediate covering of the column itself.

PROCEEDINGS OF THE

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THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

*TECHNICAL PHOTOGRAPHY.

Abstract of an Illustrated Lecture.

† FREDERICK HENIUS.

Non-Member.

If you glance at one of our modern magazines, trade papers, or newspapers, you can but wonder how life-like the illustrations contained therein are executed. You will find machinery reproductions, factory interiors and events which take place all over the world reproduced with marvelous accuracy, life and detail, and these illustrations no doubt play quite a factor in our education. We owe the advance in this direction to photography combined with the perfected half-tone process, and the modern printing press.

We distinguish today between two distinct classes of photographers, the professional, who charges for his work, and the amateur, who works on account of the pleasure and

* Meeting of Society, March 20, 1906.

† Arrot Power Building, Pittsburgh, Pa.

the recreation it gives him. He can, however, in many cases, give the professional many good points, especially in art photography. The exhibition of amateur photographs held recently at Carnegie Art Gallery showed that we possess some of the foremost amateur photographers in the world.

Photography can be divided into several different classes, such as portrait photography, art photography, X-ray photography, microscopical photography, astronomical photography, and commercial photography. The latter class comprises several separate branches, such as photographs of machinery, buildings, interiors, paintings, scenery, manufacturers' products and copying. The commercial photographer has without doubt the most difficult task to fulfill, as he must carry his outfit to the place where the photographs have to be taken, and use the light which exists, while the portrait photographer has his customers come to him and he always has the same light, which he knows and which he can control. Photographs of machinery and interiors are without doubt the most difficult branches of them all, and it is about these that I will talk to you.

Machinery photographs are mostly used for catalog and trade journal advertising, as it it impossible for the salesmen to carry samples with them. It is of great importance for the manufacturer, to obtain illustrations of his product which show the correct proportions, and if the photograph does not show it, the cut never will. It is therefore essential that the commercial photographer should be a mechanic; he should know about machinery perspective and illumination of the subjects. He should be able to suggest and know how to obtain the best results under existing conditions, and if his suggestions are carried out he should shoulder all responsibility. It is, however, impossible for such a man to obtain the best results unless he is in possession of a high grade equipment and uses the best of materials. The reason why you see so many poor reproductions of machinery and interiors, is because quite a number of large manufacturing plants are situated in small cities where no good commercial photo-

graper is available. There is a portrait photographer in almost every city, but as the machines generally have to be shipped as soon as they are finished, the portrait photographer will have to make as good pictures as he can, and in such cases generally uses his portrait lens, which is absolutely unfit for such work.

Let us now see what a first-class outfit should consist of. First, of course, is the camera. This should be built good and rigid, and strength should not be sacrificed for weight. It should be provided with long bellows, which should be parallel on the top and bottom, and only taper slightly on the sides. It should also have a rising front which when raised should not take the bellows along, and should be provided with extreme double swing. I shall explain later why this is necessary.

Next to the camera comes the most important part, the lens. There exist many splendid lens makers, especially in Europe, such as Goerz, Zeiss, Voightlaender, Dallmeyer, Roos, and Cook. In selecting lenses, you should use the utmost care. For landscape and art photography a very fine lens is not necessary, as you work for effect and not for detail. In portrait work a portrait lens is absolutely necessary; for commercial work an "anastigmat" lens only should be used. Astigmatism is a defect inherent to all the older forms of lenses, and has been approximately eliminated only during recent years in the anastigmatic lenses made possible by the new kinds of optical glass. Astigmatism means "without a point," and as used with reference to the lens, may be defined as the inability of a lens to bring vertical and horizontal lines (such as the plus sign boldly printed on a white card) to a focus at the same time, altho both lines lie in the same plane. It is important that you should understand this defect of the ordinary photographic lens, because it is its correction or elimination that the superiority of the "anastigmat" over the older lenses is apparent, and also because its elimination enables us to secure sharper definition over the whole of the picture-image, a greater angle, and consequently a greater in-

tensity, with flatness of field and covering power. Such a lens is pretty near perfection. It is without doubt the only lens to use for machinery, interiors and copying.

Before we go any farther, let us examine the various properties of lenses. You have heard people speak about focal length, aperture, flatness of field, diaphram, etc. The focal length or focus is the distance from ground glass to diaphram, when a subject 100 feet or more away from the camera appears sharp on the ground glass. The aperture is the diameter of the working part of the lens when fully opened. The depth of focus is the property possessed by a lens of giving an equally sharp image of objects situated at various distances from the camera. Correctly speaking, however, depth of focus is not a property peculiar to any particular form of lens, but to a combination of lenses. A lens working at full aperture, without being stopped down, will hardly produce sharp objects when the subjects are at a distance from the camera. By stopping down, however, considerably more depth is secured, but the illumination is sacrificed and consequently the rapidity.

Of two lenses of the same intensity (rapidity) but differing focal length, the lens of shorter focus will give the greater depth of definition. Of two lenses of identical focal length, but one having greater intensity (rapidity) than the other, the more rapid lens will apparently have less depth of focus, but when this lens is stopped down by the use of a diaphram to the same rapidity as the slower lens, the two lenses will have the same depth of focus. In other words, depth of focus with any given stop, is an invariable quality in different lenses of the same focal length, regardless of their construction.

The diaphram or stop plays quite an important part in the use of lenses. It consists of a piece of blackened metal, with a circular aperture at the center, which is placed before the lens if it is a single lens, and between the two elements if it is a doublet. An Iris diaphram consists of several segments of a circle of metal or vulcanite, working on pivots attached to a ring in the lens mount. By rotating the ring, the circular aperture formed by the segments may be made smaller or

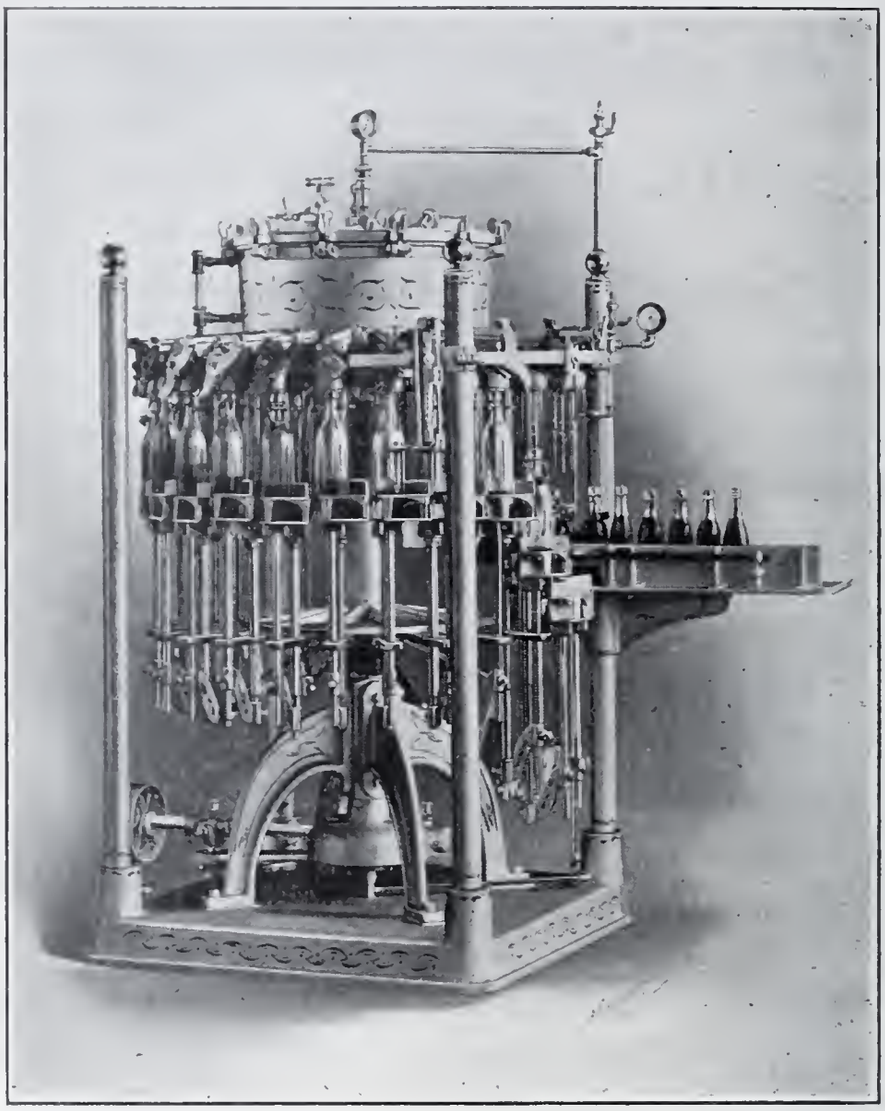
larger at will. The diaphram evens the illumination of the plate, and increases the defining power of the lens over a larger area and gives greater depth. The volume of light that passes through the diaphram is proportionate to the area of the aperture, and the areas of circles are proportionate to the squares of the diameters.

The first maxim may be simply illustrated. If the area of the largest stop of a lens be two square inches, it will permit the passage of twice the amount of light of a diaphragm whose area is only one square inch. Therefore, to get the same result, the exposure with a smaller stop would require to be double that with the larger one and vice versa. The second maxim may be illustrated thus: Suppose the largest stop of a lens to have a diameter of two inches, and another stop of the same lens to have a diameter of one inch. In other words, one is half the diameter of the other, and the first assumption would be that the smaller would require double the exposure of the larger stop. But maxim one says the volume of light that passes depends upon the area of the stop, and not upon the diameter. So we supply maxim two, which says that the areas of circles are proportionate to the squares of the diameters. The diameters of the circles under consideration are two inches and one inch. These numbers squared give a ratio of 4 to 1. So that the area of the larger circle is four times that of the smaller, and therefore passes four times more light.

We have various makes of diaphrams which have been adopted by the various makers, but the most popular ones are the F stops, and the U. S. stops. For commercial work, a lens working at an aperture of F 6.8 is fast enough for instantaneous work. It will do in almost any condition in photographing any quick-moving subject where the exposure will have to be the one one-thousandths part of a second, or even less. With a larger aperture, however, the lens has less depth, and if you have to stop down in order to get depth you are not gaining anything by using such a lens. Portrait lenses are only used with full opening, as depth is not essential—only

speed. Single combinations, even such as we find in using the front or rear of the "anastigmat" lens, should not be used, as they will show curvature.

I use nothing but anistigmatic lenses, and never use a single combination, as it can only be used for landscape and portrait work.

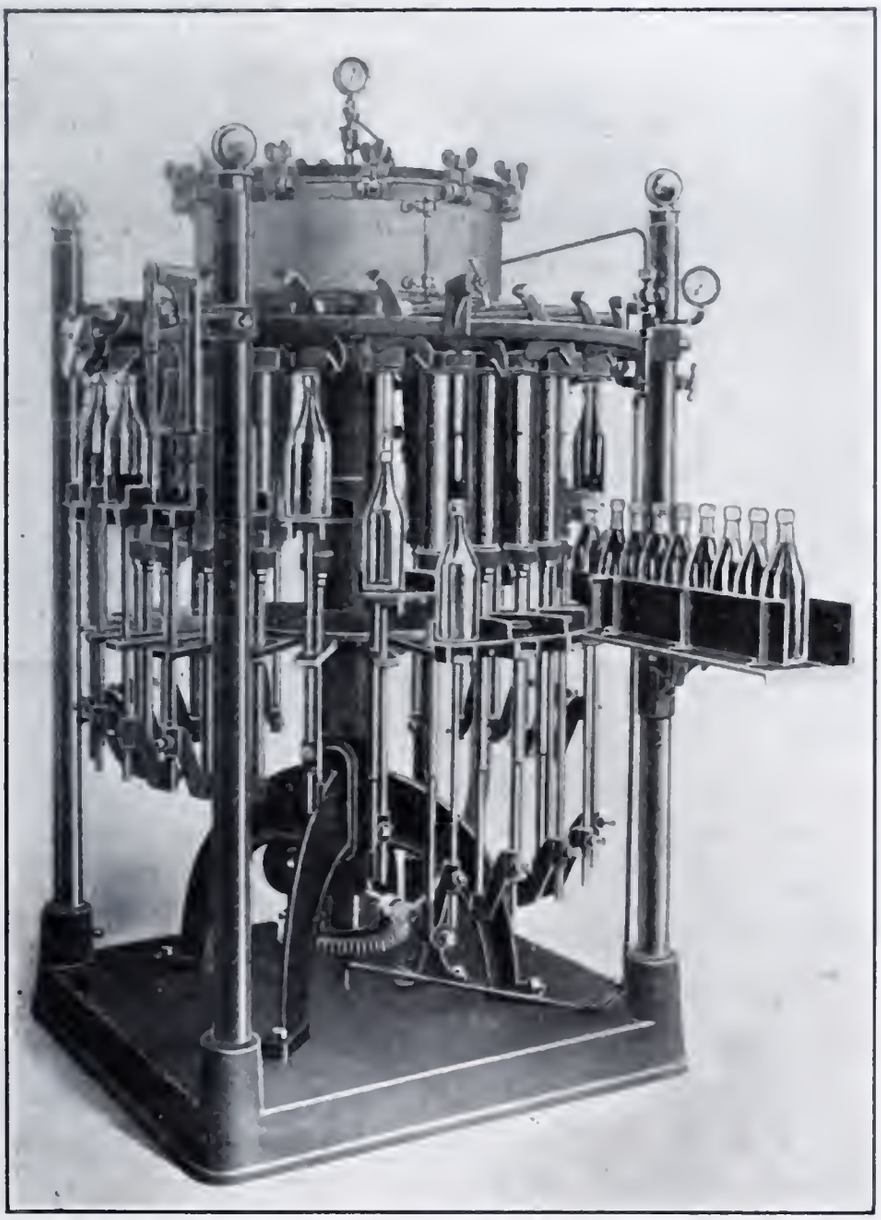


Bottling machine, not distorted.

You do not get as fine details with a single lens and you will not get straight lines. If you should take a photograph of scenery or where an artistic effect is desired, I do not believe I would use an anastigmat, and if I did would put it out of focus.

The tripod should be strong and rigid, so that the camera

will be on a solid base, as the least vibration, which often exists in machine shops or when taking exteriors on a windy day, would spoil the picture. A level is absolutely necessary in photographing machinery and buildings, as the ground glass



Bottling machine, distorted.

must be paralell to the subject in order to obtain straight and parallel lines. This is especially the case in photographing buildings. It is quite important in photographing machinery that we get a good perspective, and this can only be obtained if sufficient distance from the machine to the camera can be had. Perspective does not depend upon the lens used,

but is governed entirely by the distance from the subject to the lens, and nothing else. If we get too close to the machine we will find that the parts nearest the camera are too large compared with the parts farthest away, and we get a machine which looks distorted.

Illumination is another important factor. Most machines are too large to move around and you will have to take them under the conditions which exist in the shop. But where the machine can be moved, the light should, if possible, come from the upper left-hand corner, illuminating the front and the side of the machine where a three-quarter view is desirable. The front and side should not be illuminated exactly alike, as we otherwise kill the contrast. We all know that a picture consists of lights and shadows, and if we get too even a light we obviate the shadows and get a flat picture.

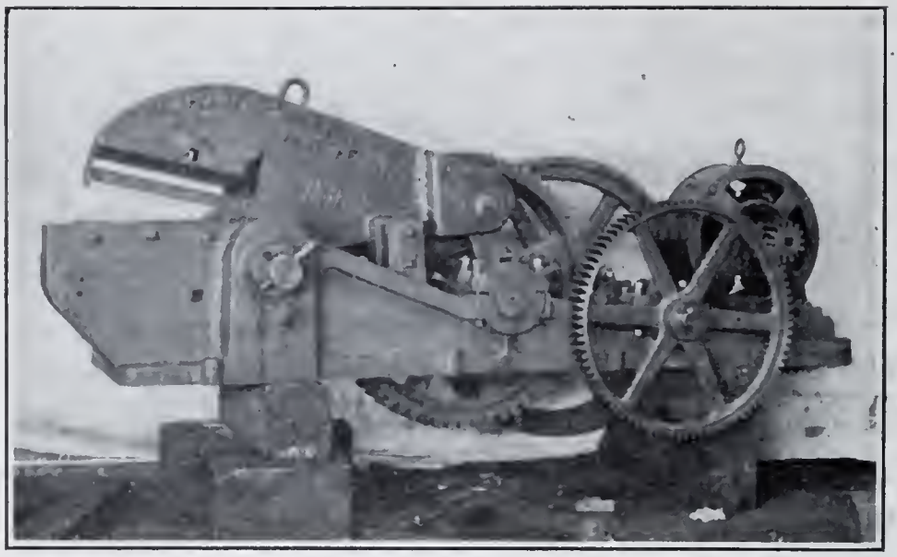
I had an experience with the Cooper Hewitt light five years ago, while they were in a rude state. For copying wash drawings they were excellent, but when you came to copy a colored photograph you got into a lot of trouble on account of the bluish cast. We made some enlargements without using a condenser, and they gave a pretty even illumination. The power of the light is very deceiving, and is quick indeed. I believe that if you could get familiar with these lamps you could accomplish a great deal with them. They use very little current and do not radiate much heat.

Photographing buildings is quite a difficult task, as most of them are quite high and the distance limited. In such cases an extremely wide angle lens will have to be employed and the perspective will not be right. Interiors usually have to be taken by the light existing, but in many cases flash light will have to be used. This is especially the case with interiors of power plants, which are frequently installed in the basements of large office buildings. You have noticed, in many exteriors and interiors, that a certain amount of halation appears on the photographs. This is caused by the light passing through the film and striking the glass. A double coated plate should always be used for such purposes, as they

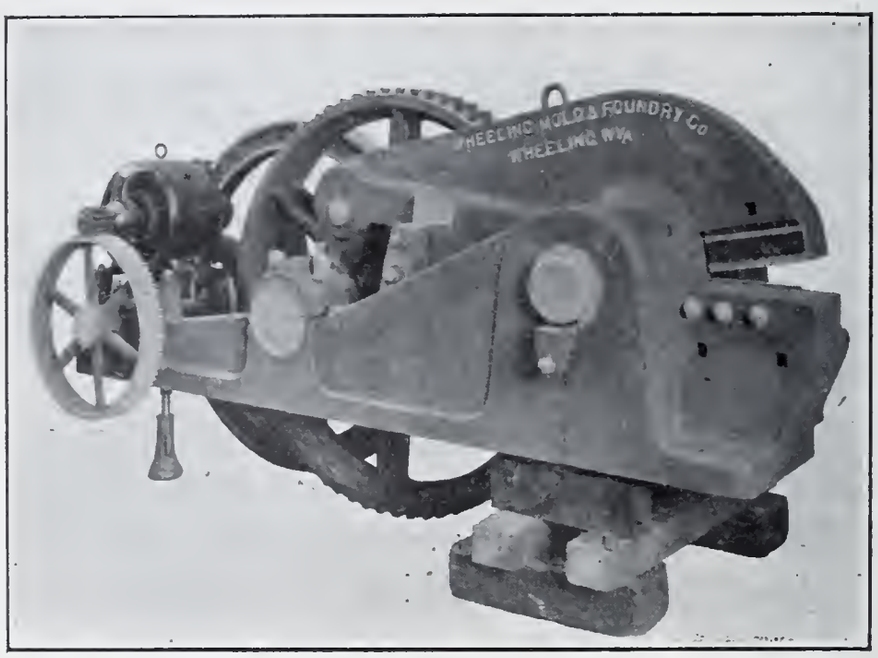
do away with the halation to a certain extent. An interior where lots of windows are included should never be taken against the source of light. The source of light should always be behind your camera. In photographing machinery, a large back-ground should be secured in order to get distinct outlines of all details. It is also necessary to lay quite a lot of white paper around the bottom of the machine, separating the base of the machine from the floor of the shop, as it is otherwise quite difficult to get the outline. The bright parts of the machine should appear bright, and should not be painted with any color. The rough parts of course should be painted with a smooth gray flat color.

In making the exposure of a machine, we must consider the height of the camera from the floor. In many cases, say for a small machine, we might get up too high and would get a very bad perspective, while in photographing larger machines it is necessary to put the camera up on a platform. The exposures should be liberal. A correctly exposed plate is very seldom found, but when we are using a double coated plate we have considerable leeway in developing, and we can give our pictures full time.

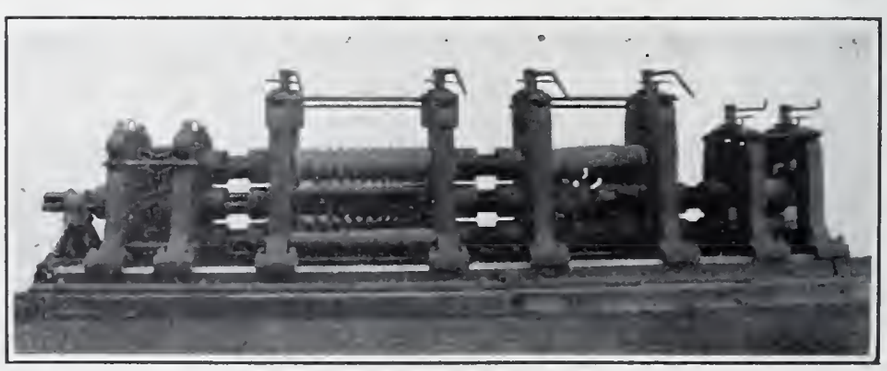
It is quite an important factor to know how to develop, as any plate of a machine may be ruined or saved by improper or proper developing. It is almost impossible to develop a plate of a machine or an interior by submerging it in the developer. Local developing should be adhered to, and the plate should be developed very slow so that the progress can be watched. The double coated plates of course are more difficult to develop than the single coated. It takes longer to develop them, longer to fix them, longer to wash them and longer to dry them; besides, these plates are more expensive than others, but nevertheless they are the only plates to use. A clearing and hardening bath should be used, especially in summer, so as to prevent the plates from frilling and in order to give you clear plates. You should always use the same developer on the same plate, as the same developer does not work the same on two various brands of plates, and two



Shear, not distorted.



Shear, distorted.



Rolling Mill. Bottom of machine curved, caused by using single combination lens.

developers do not work alike on one brand of plates. You must study your plates and your developers if you wish to get good results.

Here is the way developing is mostly done: In five seconds the image appears and in about a minute you are through with it. That is the way most people do it. They can't wait until the plate fixes and washes, and they can't wait until it dries before they want a proof. Now you must not force things. You must develop in a diluted developer and use local developing. Take a developer which would develop a plate in ten minutes, dilute it ten times, and you have one hundred minutes. Dilute it sufficiently to take seven or eight hours to develop a plate, insert your plates in the tank and the next morning they are all developed. They use this tank system a great deal in England. I never tried it, but it ought to be a very good thing. Develop a plate slowly and you have a chance to rectify any fault. When the image comes out put the plate in water and let it stand awhile. Look at it occasionally, put it in the developer again till you have got all the details out; after that is done put the final strength to it.

The developer I have been using for several years has a peculiar action. It kills the actinity of the plate to a certain extent when I have it in the developer about four minutes. They have developers today with which you can develop and fix at the same time.

A special case is developing a picture of a spot of light that is moving rapidly. In that case I would use a contrasty developer. I would use a slow developer until I found what the plate contained, and then use a strong developer to get final strength. A very good developer for under-exposed plates is amidol. Amidol is good for all kinds of snap shots, which are under-exposed plates. Sometimes you have to photograph a white building against a blue sky. The white building and the sky appear absolutely white on the plate. The way to avoid that would be to use an isochromatic plate so as to get the values of the blues. I should choose the light at a certain part of the day, say about sunset;

you would then get more contrast. You can always either exaggerate or reduce the contrast in a plate, therefore you should always start slow and when your image appears modify your developer as you go along. You can "fake" your print afterwards all you want.

In order to restrain the high lights, while you bring out the detail in the shadows, develop the plate until the high lights appear, then lay it in water, leaving it there a little while. Use, of course, a two-solution developer, which should be mixed according to results wanted. If you should get too strong high lights you can reduce them with ammonia persulphate 1 to 10. Stop it afterwards with a ten percent solution of sulphite of soda. Ammonia persulphate reduces the plate in the same proportion as you develop it; the high lights that came out first are reduced first.

With isochromatic plates you have to work at a considerable distance from the light. You should cover up the plate instantly when you start it. I use ruby light and yellow light and tissue paper in between.

For isochromatic plates I use two trays. I do not use isochromatic plates except in copying colored pictures or oil paintings, and do not see much use for them if you are only going to use the photograph for cuts. When you take a photograph of a valuable oil painting, one of the old masters, you must use them, as such copies are used for framing and must possess all of the values contained in the original. In Berlin they have a gallery for copying oil paintings, and they have a motor attached to the entire gallery so that it moves with the sun. Everything is screened off so as to permit only the rays of the sun to strike the picture. You have to have a tremendously strong light to get the values out and cannot get proper results with a daylight exposure, especially with copies of the old masters. I photographed quite a lot of oil paintings at the Carnegie Art Exhibition and had all kinds of trouble. The gallery has light from four sides and there is no place to put the picture where you can get light from one side only. I tried everything possible but could not overcome reflections.

A ray filter might or might not help. I am not very much

for ray filters. They are very good for oil paintings, flowers and water colors, but when it comes to rectify values for one color they destroy them for another. When you take a picture of a high building you raise the front as much as you can and tilt the camera, then you apply the level to the ground glass, you must not tilt the ground glass any farther than your level permits. The moment your swing back is pulled out as far as it will go and remain level, your limit is reached, and you must remember that by tilting it you are losing depth. The best way is first to raise the front as far as the light circle permits; if you still cannot get the picture, tilt the camera. You might rectify a distorted photo in copying by tilting it.

Non-halation backings are claimed to prevent halation, but I have never tried it. They have some plates backed with paper and some with a painted back. I would rather buy a double coated plate. They say the backing does not hurt the developer, but it colors it, and they charge about as much for these as for double coated plates.

Films are practically non-halation. The film has a mat surface on which the coating is applied.

In printing, various papers can of course be employed. For half-tone reproductions, solio paper should be used, and the prints should be ferrotyped, so as to minimize the grain of the paper, as it generally shows in half-tone reproductions. For scenery and art work platinum paper is the only paper to use. It gives you a very artistic effect, but of course some detail is sacrificed, as the paper has a rough surface, but in art work we only consider effect and not details.

I saw a Chicago photographer take a flash light of about 700 people in the Auditorium. He was on a platform about 20 feet high. He had a lot of non-inflamable muslin bags about six feet long hung from the ceiling. A charge of instantaneous flash light powder was placed inside each bag and an electric circuit connected them. He closed a switch, the powder exploded, the light was diffused through the bags and the smoke was all retained inside them. After taking the picture the bags were carried outside and emptied of their smoke.

*ORNAMENTAL IRON WORK.

A TOPICAL DISCUSSION.

W. N. Kratzer, Member—The subject of ornamental iron, as I have found it, covers quite a wide field. It takes in practically everything that the structural iron man does not want, consisting of stair work, elevator enclosures, balconies, verandas, fire escapes, gratings, grilles, pavement lights and miscellaneous iron work. The work usually comes from the architect's office, and we find it in various designs, ideas and suggestions as to details. Often it becomes a matter of very great importance to the manufacturer that a reasonably correct interpretation of the intended details be had before estimating the work, to avoid underestimating the cost necessary to execute the work according to details later developed by the architect, or for his approval. I have in mind some pilaster columns that indicated a simple panel finish. When it came from the architect's hands it was embellished with acorns, leaves and foliage. The patterns alone represented a cost greater than the contract price for the columns.

In stair work we find that stringers composed either of cast iron, channel or plate and angles ornamented or finished off with ornamental molding, each have their advocates, but where fine castings are not obtainable, the architect will often wisely allow the design being changed from cast iron to steel plate and angles and molding, which really makes the smoother and better job. It is frequently a delicate matter to take up these points with the architect. He is apt to feel that the manufacturer or constructor desires to make the change favorable to himself. Those changes are not always favorable to the manu-

* Meeting Structural Section, Morch 27, 1906.

facturer, but are generally made with a view to obtaining better finish, as well as to simplify the connections and thus expedite the work. The design may be such that it would be generally pleasing and acceptable when completed, yet the connections or details as they come from the architect's office are not always practicable, and at times are almost impossible. I have in mind one case where I desired to give the architect something better and more expensive to execute than he asked for. The design was clumsy, indicating wood construction, heavy balustrades, and heavy in every respect, something that would gather dust and look unsightly. I suggested to the architect that the entire stairs (except the treads, which were marble) be made of wrought iron instead of cast iron, to make it light and airy. He asked me to submit design and details. I had the design and details prepared and submitted, but it was not exactly what he had shown by his drawings, therefore was not what he wanted. I submitted another design that would cost considerable more to execute than the work he had designed, and with the same result. After the second trial he put his own draftsman on the work and produced his own details. We built what he asked for in the first place. He got what he wanted, but he might have gotten the same effect in wood at less cost.

In the way of ornamental grill work, we are often called upon to produce work in the way of flowing designs of wrought iron, yet which could only be reproduced by casting. Flowing designs of an irregular form, thickening and diminishing in section, with difficult angles and combinations, should not be made of wrought iron. One of the features in ornamental iron work is to aid the architects and engineers to modify their views to practical details and connections, so that the work can be constructed economically and expeditiously, and at the same time preserve the original design as nearly as possible.

I have found the business of manufacturing ornamental iron work at times an expensive luxury. It is work that is hard to estimate the probable actual cost, because the con-

nections and details are not clearly shown on the drawings by which the work is estimated. When it is finally developed and worked out it may mean a great deal more expense than contemplated.

We find, in connection with ornamental iron business, difficulties all along the line, yet it is a business that appeals to a person who has a liking for ornamentation. I always felt that I would like to build up a business in the ornamental iron line, and be able to handle anything and everything, but find in Pittsburgh it is difficult to obtain materials, especially iron castings of the necessary smoothness and finish, at such a price that you can compete with concerns in other parts of the country. In the wrought iron line we have the materials and the mechanics, whom I believe are as capable as any, with the exception of smiths for leaf and hammered work. We do not have the facilities here to handle large work. For fine ornamental castings we usually have to go East or West. Concerns located in Illinois, Ohio, Indiana and in the East pay a lower rate of wages with few exceptions. Their employes are recruited from the farms and smaller villages. They live right there, work at a low rate of wages, grow up in the business, and become skilled in their special line, yet you cannot take them from their homes and bring them to Pittsburgh and obtain satisfactory results. I have tried it on different occasions and it has proven a failure. The men I have brought here were capable in their own line in their own way, but were not satisfied with the new surroundings and conditions. They had heard of Pittsburgh being a great money center, and the rate of wages being high, and they were never satisfied. Yet I paid them more than they were worth, and much more than they received at home. My experience in the manufacture of structural steel, as well as ornamental iron, is that the mechanics you collect in and about Pittsburgh are the most satisfactory. If they are given the opportunity they can produce the work; but ornamental work costs anywhere from 25% to 30% more to manufacture in Pittsburgh than in the localities I have mentioned.

I have found to my own satisfaction that as a business manufacturing ornamental iron is hazardous, and it is those concerns who have had the perseverence and pluck to live through all the disappointments and losses, and finally establish themselves as manufacturers of ornamental iron, who are today getting the preference in the business. There is no shop in Pittsburgh that pretends to compare with several of the Western and Eastern shops. They have built themselves up through years of experience; they have surrounded themselves with all the facilities for handling this work; they are in cities where ornamental iron has been in vogue for years, whilst in Pittsburgh it is practically new. In Pittsburgh it is only in the new buildings that you will see the really ornamental handiwork. Therefore Pittsburgh up to the present time has largely drawn its supplies for ornamental iron from the East and West.

As to the quality of steel or iron in ornamental iron work we use soft steel and refined iron. For forgings we use refined or Swedish iron. For cold work and scroll work we use soft steel.

Chester B. Albree, Member—Pittsburgh is not a good place to manufacture ornamental iron work. Mr. Kratzer's experience has been my own, that it is impossible, unless you have your own foundry fitted up for the work, to get any ornamental castings in Pittsburgh. This is rather hard on our foundries, but the reason is quite obvious. The job founders principally make machine castings, heavy rolling mill castings and that class of work. It requires a strong iron, but not a fine running iron. A fine running iron usually has a good deal of phosphorous in it, such iron as is used in stove castings, etc., and is not strong. We have tried stove foundries and while we would get very beautiful castings they were very poor stuff; they were not suitable in point of strength for ornamental castings. Where you expect to make thousands of pieces, it pays to have metal patterns with the highest polish, but for ornamental iron work the patterns are different in every building, and until these last office buildings it was

necessary to use new patterns for every flight of stairs. Under these conditions it is impossible to make metal patterns; and wooden patterns, especially after they have been changed a few times, get pretty shaky, and sending them to the stove foundries is useless. The ordinary foundries cannot handle them; unless there is enough business to justify a foundry doing that work exclusively, it is almost impossible to make that fine class of work. I discovered that a good many years ago and quit. The result is that the Eastern and Western concerns, who have finer sand and who have made a specialty of such work, putting in electric bronzing plants, grinding plants to grind the castings, doing wax modeling for the first model and having plaster molds and all that sort of thing, are doing the business. It requires an investment of a million dollars to have a complete plant, such as the Hecla Iron Works and the Winslow Brothers Iron Works, works employing from 1,200 to 1,500 men, and putting out a beautiful line of work. But it is out of the question to make that work in Pittsburgh under present conditions.

I read a paper on ornamental iron work before this Society several years ago, and at that time I showed some samples of fine mouldings and they were wonderful. I showed them to some Pittsburgh rolling mill men who thought that what they did not know about rolling shapes was not worth knowing. They expressed themselves as stumped; they never saw anything like it. Some of those mouldings are as large as eight inches with elaborate designs, and are not over an eighth of an inch thick, and rolled with embossed rolls too. I saw some mouldings of a different character, in that they had no embossed work, and were drawn cold from soft steel. They are perfectly smooth and polished with the cleanest corners and beautiful curves. The material is drawn steel, made in light gauges, from about No. 12 up to 16, 18 and 20. It costs from two or three cents up to forty cents a foot. They are very beautiful and I speak of them as a remarkable example of what can be done with steel today. They are manufactured in Jamestown, New York.

In the Shelby Tube Company's office in the Frick Building I saw some samples that they have drawn recently. They have drawn seamless tubing over various shaped dies, producing work very similar to the Jamestown work, but not so good; at the same time it shows what can be done with rolled steel.

They make door frames and the doors themselves, and all kinds of ornamentation, out of these mouldings, taking the place of wood in buildings where they want fireproof work. The ornamental iron work today made by some of these specialists is on a par with the best you will find in Europe. Furthermore, it used to be that the wrought hand work in Europe was a perfect marvel; but today you can see in New York and Chicago, and to a limited extent in Pittsburgh, work that will hold its own with any of that fine European work of the 16th, 17th and 18th centuries. It is merely a question of getting your men and having the facilities to do the work. As it is now in Pittsburgh, there is very little inducement to go into ornamental iron work.

F. B. Bissell, Member—The Pressed Steel Car Company has recently organized a department for the purpose of building steel passenger cars. Not only is the framing and exterior to be steel, but the interior finish also as far as possible is to be of steel. Window frames, doors, paneling, moldings, in fact almost everything can be of steel except covers for seats, window glass and trimmings. Of course, there are other materials nearly as good for inside finish, but what we want is a really fireproof construction. Aluminum and bronze are sometimes used, but I think steel is the best.

Regarding the drawn steel Mr. Albree mentioned, we had a gentleman at our office the other day who showed some samples of this ornamentatal steel that were very fine indeed. He showed some imitations of mahogany and other woods that could not be told from the real thing. This finishing is enamel and is baked on, as is the finish of first-class bicycle frames, and it is impossible to remove it. One great difficulty in all steel construction for cars is that the inside is liable to "sweat" because of the difference in temperature between the

inside and the outside. Moisture is liable to condense on the inside and you have to guard against it. That is one of the problems that we have not completely solved yet. We believe we can protect the inside metal with something like asbestos or fireproof paper placed behind the finish.

We have at present considerable wood finish in a car, which is rather objectionable in that it does not render the car completely fireproof. But as people seem to greatly prefer the wood finish to the metal, it seems advisable to make the steel a good imitation of wood. Some of the cars built for the Interborough Railroad of New York are finished in aluminum. The pure metallic finish does not seem to take as well as the natural wood finish. I believe in time we will have practically the whole car of steel, and at the same time have all the ornamentation the most beautiful in appearance, and perfectly fireproof. We have not succeeded yet in turning out a car with steel for all the inside finish, but we are working toward that end.

A great deal of our steel is pressed, but the best mouldings are the drawn steel. It is more lasting and more beautiful than any wood work possible. It is a little hard to fasten on, as it is necessary to have screws, and they show on the outside, because the stuff is very thin, not more than $\frac{1}{16}$ or $\frac{1}{32}$ of an inch in thickness. We may be able to so secure it that even the screw heads will not show, and thus we may have a perfect imitation of wood.

Soldering might possibly be done, for the frame is all steel. We will have to have some asbestos liners, as I said before, which may interfere somewhat. But I think soldering is unsuitable unless very well done, because the cars are subject to so many strains that it has to be fastened very securely.

H. H. Anderson, Member—There is a firm in the city now that has a solder the tensile strength of which is about 20,000 pounds per square inch. I got some repairs made not long ago, as did the Pressed Steel Car Company with this same composition, and it gave a higher tensile strength than cast iron. In securing the mouldings, etc., it would be much

superior to screws or rivets if it could be adapted to this class of work.

K. A. MUELLENHOFF, Member—These shapes are made at Cologne, and they have several hundred different patterns, but it does not pay very well. It is an expensive luxury. For connecting they sometimes use screws with round heads and a little square extension, and after the screw is driven home the extension is filled perfectly smooth, and you see only a row of semi spherical dots that look like a form of ornamentation. Where it requires a very fine finish with some parts coming together at very acute angles, they may be welded together by means of an oxy-hydrogen flame; that gives a perfectly smooth appearance. You cannot see the joint and at the same time the strength of the material has not been impaired. In many cases where there have been experiments the pieces broke at some other place than at this weld.

As for that cast iron work, I want to call attention to one point. I have been connected with a company which does much ornamental work and when there was no article that could be made in thousands from a metal pattern, they used a plaster of paris pattern, reinforced with wire. The molds were made of loam with very little sand in it. It was not easy to do, and men must have special experience, but you get a perfectly smooth casting. It is sometimes possible, not as much in building as in bridge work, to use common structural shapes for ornamental purposes, as is done on a bridge built some years ago in Leipsic.

Another instance is the electric elevated railroad in Berlin. It is constructed of beams and between these beams are buckle plates. To cover that at the end simply by a plate did not look very nice, so they cut the plates to form small arches, seamed by a curved strip of flat iron and fastened with small rivets. It looks like a very nice decoration, and if any of you happen to go to Berlin and will look at this elevated road you will see it gives quite a different aspect from the New York elevated. It actually looks like a decoration for the town, and nobody could say that of the New York elevated. It can often

be done in a very simple way without using expensive castings, simply using our structural shapes and structural work without much extra material or labor.

C. B. Albree—That sort of work in America comes rather expensive; at the same time in some places they have more appreciation for the beautiful than they have in Pittsburgh, they are specifying it. For instance, in Boston and in New York today they are using just such ornamentation in their structural work; it adds a great deal to their appearance, and yet preserves all the structural features.

L. C. Moore, Member—When Mr. Albree spoke of drawn steel I was puzzled, but it occurred to me directly that it was probably rolled flat, hot, as near the size as possible, then cleaned and again rolled by the cold rolling process. Instead of the so-called drawing, it is rolled by means of what are termed male and female rolls, setting apart just the thickness of the sheet. I can see that it is possible to make almost any shaped moulding in that way, but it would be utterly impossible to draw anything of that kind.

C. B. Albree—I asked about that because I knew that such shapes had been rolled on mandrils, but was told most emphatically that it was drawn through dies as you draw wire. They had some forms that cannot be possibly made by rolling, for you have to have clearance to roll. They were not like the German moldings. The German moldings instead of being very thin were of perceptible thickness, say ⅛ to ¼ of an inch. The remarkable thing was not that they could roll it in this shape, but that they could roll it with the relief ornamentation so clean.

L. C. Moore—I can understand how it can be done with split dies, and the metal drawn through them. Two dies can be made, one to fit the other, and space them apart just the thickness of the metal. Then you can form a low carbon steel into almost any shape. I think our Pittsburgh bridges are the worst I have ever noticed in the matter of ornamental

work, and I believe I know a reason for it, which is that some of them were changed from wire suspension to eye bar suspension. I think that was the case with the Point bridge which ought to have fallen in the river instead of being rebuilt. My idea of bridge architecture is that the designer does not expect that you will go up close and look at it with a magnifying glass, but he expects that you will stand a quarter of a mile off and look at it. I think that the Wabash bridge is handsomely designed to look at from a distance, and the new cantilever bridges are all works of art in one sense of the word.

W. N. Kratzer—The ornamental work that is handled around Pittsburgh is the miscellaneous ornamental jobs on buildings of eight or ten stories. The 16, 20 and 24 story buildings are all fitted out by either New York, Chicago or Cleveland firms. I would like to see the time when Pittsburgh would have a fully equipped up-to-date ornamental iron works. Pittsburgh should be able to support such a works. As Mr. Albree states, however, it would be out of the question to maintain such a plant without a foundry thoroughly equipped and manned with men experienced in that line, and of course you have to have the material to suit the work, fine sand and loam and men skilled in that work.

I remember one piece of work on the T. C. Jenkins building. The facia and soffit plates in the cornice work around the first story windows, fronting Penn Avenue and Liberty Street, are about 18 feet long and paneled. They are as smooth as a rolled sheet. I could hardly believe they were cast iron. I noticed that some were cracked on the inside, the concealed side. In cooling the casting, some had warped, and had to be cut on the back, just enough to straighten them, and then backed up with steel plates, drilled, tapped and tightly screwed on and drawn straight.

*BRIQUETTING OF BROWN COAL.

† K. A. MUELLENHOFF.
Member.

Our ordinary coal is the product of a process of slow distillation of the remnants of an enormous vegetation of long by-gone days, of the so-called Carboniferous age. But, also, in far less remote times, the world was covered with a really tropical vegetation, and this seems to be true especially of the Tertiary period. Wherever we strike areas of Tertiary deposits we almost invaribly find more or less extensive deposits of its vegetation in a state between a well hardened and dried peat and a material similar to our ordinary coal of a lighter or darker brown color, the so-called brown coal. Partly, it has still the decided structure of the wood it originated from and may be called lignite, but many deposits seem to have been formed especially by accumulation of grasses, lichens and mosses and they do not show their wooden structure. I will use, therefore, the common name of both—brown coal.

This coal is generally found in deposits varying from 7 to 100 feet in thickness that seem to have filled Tertiary lakes and swamps; they are generally near to the surface and little disturbed, so that they can be mined in the open, though there are also underground mines. Sometimes there are several beds, one above the other, as at Rauen near Berlin, where there are seven deposits.

Brown coal contains considerable water, the average of a great number of analyses showing 45%, due to which it is impossible to store the coal for a long time in the open air as it would soon crumble into a loose mass; its heating value also being lowered from 2,500 to 4,000 B. t. u. per lb. Formerly its use was limited to domestic heating and some boiler

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* Meeting of Society, April 24, 1906.
† No. 813 Franklin Avenue, Wilkinsburg, Pa.

firing in the neighborhood of the mines, as the high percentage of water prohibited its shipment any considerable distance.

The world's production of coal in 1896 amounted to 532,785,000 tons (metric).

Great Britain, 198,478,000 tons, or 37.25%.

The United States, 170,243,000 tons, or 32.00%.

Pennsylvania, 88,943,000 tons, or 16.7%.

Germany, 85,690,000 tons, or 16.1%.

But besides that, there were mined in Germany 26,780,000 tons of brown coal, or 32.4% of Germany's ordinary coal production and 5.2% of the world's ordinary coal production. In all Europe there were mined, besides 361,088,000 tons of ordinary coal, 57,076,000 tons of brown coal, equal to 15.8% of the coal production of Europe, or 10.7% of the total coal production of the world. That is an amount worth considering and it has increased rapidly since that time, though I could not get the complete statistics for a later year than 1896. I believe the percentage is more likely to have increased than to have decreased, in spite of the enormous increase of the coal production throughout the world, and especially in this country where it has more than doubled since that time.

The northern part of Germany is a plain about 150 miles wide and 650 miles long completely covered by glacial drift, but below that there are large areas, hundred of miles in extent, covered by thick beds of brown coal. Parts of this coal, especially near Halle and Leipzig, are so rich in bitumen that they have given rise to an extensive chemical industry, but the largest part that is now mined is used for the fabrication of briquettes.

The name briquette is of French origin and means a little brick, because the first coal briquettes had this shape; but now it is applied to a great variety of bodies pressed from particles into almost every shape, as coal briquettes made from coal dust and slack-coal, peat briquettes, and last but not least, briquettes from brown coal.

The process of briquetting brown coal is practically the same everywhere and consists in disintegrating, drying and pressing the coal into the desired shape. I will give a descrip-

tion of the briquetting plant of the Lauchhammer Company, a well known iron and steel works in Saxony. But, before entering into details, I must call your attention to the fact that the process of briquetting brown coal is entirely different from the briquetting of anthracite, coal dust and slack coal, for in this latter case a binder has to be used, while with brown coal no binder is necessary, the raw material containing sufficient bitumen to give fairly hard and weather proof briquettes. Besides that the main difference lies in the high pressure used with brown coal.

The chief centers of the briquetting industry are in the Prussian provinces of Saxony, with the adjoining parts of Brandenburg and Silesia, and near Cologne in the Rhineland, where the briquetting works meet successfully the competition of an enormous coal mining industry. But there are large deposits of brown coal spread over the whole country that are hardly touched. One deposit in the Rhine province, of a thickness varying from 66 to 330 feet, is estimated to contain at least 3,000,000 tons of coal, and there is another bed of brown coal beneath it. In 1901 there were 42 works located on this deposit, with nearly 6,000 hands and an annual output of 5,202,274 tons. Still more important are the deposits in Saxony, where there were, in the same year, 309 works with 33,000 hands and an annual output of 28,008,701 tons of brown coal. The total output of briquettes amounts to probably 14,400,000 tons, as there are about 800 briquetting presses in Germany, each producing 60 to 70 tons per day. The Lauchhammer Company owns a large tract of land, mostly covered with pine woods, but beneath is almost one large coal bed, from 20 to 50 feet thick, covered by peat, sand and clay 10 to 30 feet thick. They erected, in 1901, a briquetting plant, which makes them almost independent of foreign fuel for the greater part of their iron and steel works, as the heating, enamelling and open hearth furnaces can be fired by the gas produced from brown coal briquettes, and the boilers fired with them directly.

Brown coal is mined there in an open pit, as is done generally if the cover is not thicker than the coal bed itself. The cover is taken away by large steam excavators of the

chain and bucket type. The coal stands in vertical walls, so it has only to be loosened by picks and it falls into small wooden hoppers that may be easily removed. From these hoppers it is loaded into cars, each car containing about 0.8 cubic yards, which run on tracks of 2 feet gauge, mostly by gravity, to the main track, and are there coupled to an endless chain which hauls them up to the third floor of the briquetting works, a distance of about 4,000 feet, and a total lift of 100 feet. The electric motor for this chain is rated at 50 horse power, but in regular service there are seldom required more than 35 horse power. The bottom of the pit being about 40 feet below the surrounding country, it has to be drained. This

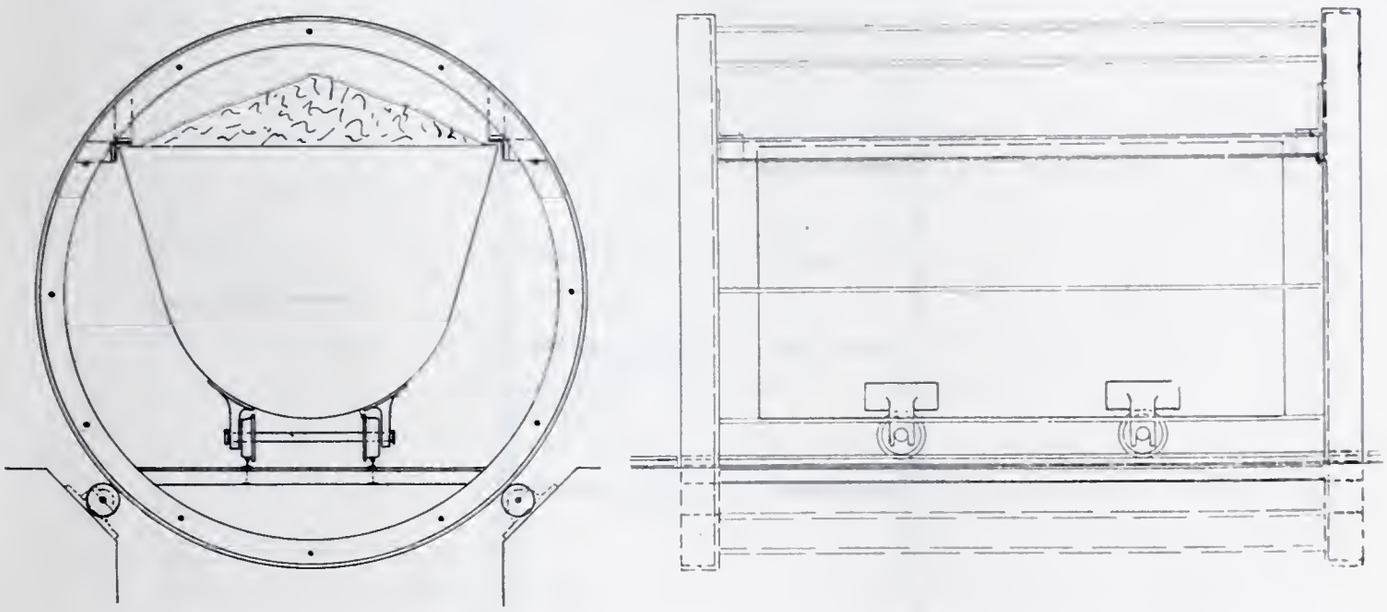

Fig. 1.

is done by two motor driven pumps, each with an electric motor of about 35 horse power and a capacity of 600 gallons per minute against a head of 50 feet, a smaller pump draining the deepest part of the pit into the sump of the main pumps. As the coal standing in the air has a tendency towards spontaneous combustion, especially in dry summer weather, a line of pipes with the necessary hydrants is run from the delivery pipe of the pumps through the whole mine, so that every point may be flooded easily. The up-going track reaches its highest point just outside of the building, at a point a little higher than its third floor, and while the chain continues towards the head sprockets on the fourth floor, the loaded cars

run by gravity to one of the car dumpers (a, Fig. 2) or to the coal bin in the adjoining boiler house. Sometimes the coal contains a good deal of sand, or pieces that are more wood than coal, and cars containing this "junk coal," as it is called, are marked so that the switchman can sidetrack them to the boiler house. The car dumpers (Fig. 1) consist of a short piece of track a little longer than the car itself, attached to two rings of angle iron which revolve easily on small rollers in the floor. Two straight angle irons connected the rings at the upper edge of the cars, thus preventing them from falling out in the reverse position. Rods connecting the rings are used as

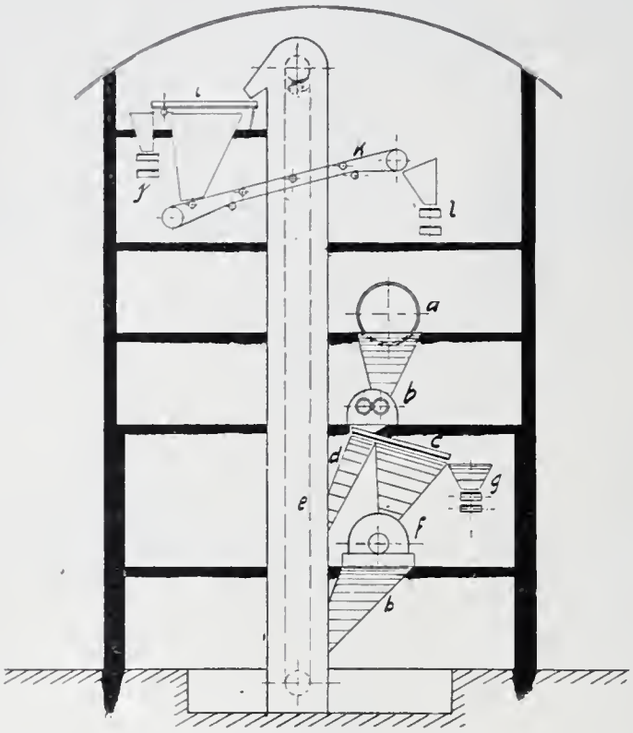

Fig. 2.

grips by boys handling the dumpers. As soon as a car is stopped in the dump a boy jumps on one of these rods and the dumper begins to revolve. As the center of gravity is above the center of the rings as long as the cars are loaded, this impulse is sufficient to overthrow the dumper and the coal falls into the hopper below the car dumper. The center of gravity being now again above the middle of the rings, a slight pull brings the car again into an upright position. The next car pushes the empty one from the dumper on to an inclined track, on which it runs back to the incline and under the endless chain going down to the mine.

This is the last handling of the coal by hand. From the dumper it is handled automatically until the briquettes are loaded into the cars, and only a small number of men are required to look after the machinery. I will mention here that the Lauchhammer works were the first to use individual motor drive for nearly every machine.

From the hoppers the coal passes through rotating crushers (b, Fig. 2), each consisting of two rolls 20 in. diameter, rotating in opposite directions and with teeth over their whole surface, which breaks the coal into small pieces. From the form of these teeth we call the rotating crushers "breaking wolves." The motors for these crushers are rated at 15 horse power. The coal falls now on shaking sieves (c). The coal that passes through the ⅜ in. meshes at the top of the inclined sieve falls through the small chute (d) to the elevator (e); the remainder passes through the sieve with 2¾ in. meshes and falls through the hopper to the disintegrator (f), and the remainder, chiefly pieces of wood, fall on a belt conveyor (g) transporting the material to a small elevator at the end of the building. This elevator throws the material on another belt conveyor which distributes it, together with the slack coal from the belt conveyor (j) at the end of the sieves, over the coal bins in the boiler house. The disintegrators (f) each consist of two steel discs, which have rows of steel projections on their inner sides. The discs are driven by a 22 horse power motor, 2,000 r. p. m., and rotate in opposite directions. The coal passing between them is ground into small pieces, thence falling through the chutes (h) to the elevators (e).

These elevators lift the broken coal, now called "knorpel," to the uppermost floor of the building and empty it on horizontal jolting sieves (i) which separate the pieces of coal of proper size up to ⅜ inch diameter; the remainder, falling on the conveyor (j) are transported to the boiler house. The clean "knorpel" is taken by the conveyors (k) to the other side of the building and falls there on the main conveyor (l) that runs through the whole length of the house connecting all the systems described thus far, and transports the material over the fire-proof dividing wall to the other department of

the plant. The part of the work just described is called the wet-house or wet service, because the coal still contains its hygroscopic water; the rest of the house forms the dry service. The wet service runs every day, except Sundays, as long as they are working in the mine, and has to handle all the material required for the dry service, which runs continuously from Monday morning to Sunday morning at 6 o'clock. As

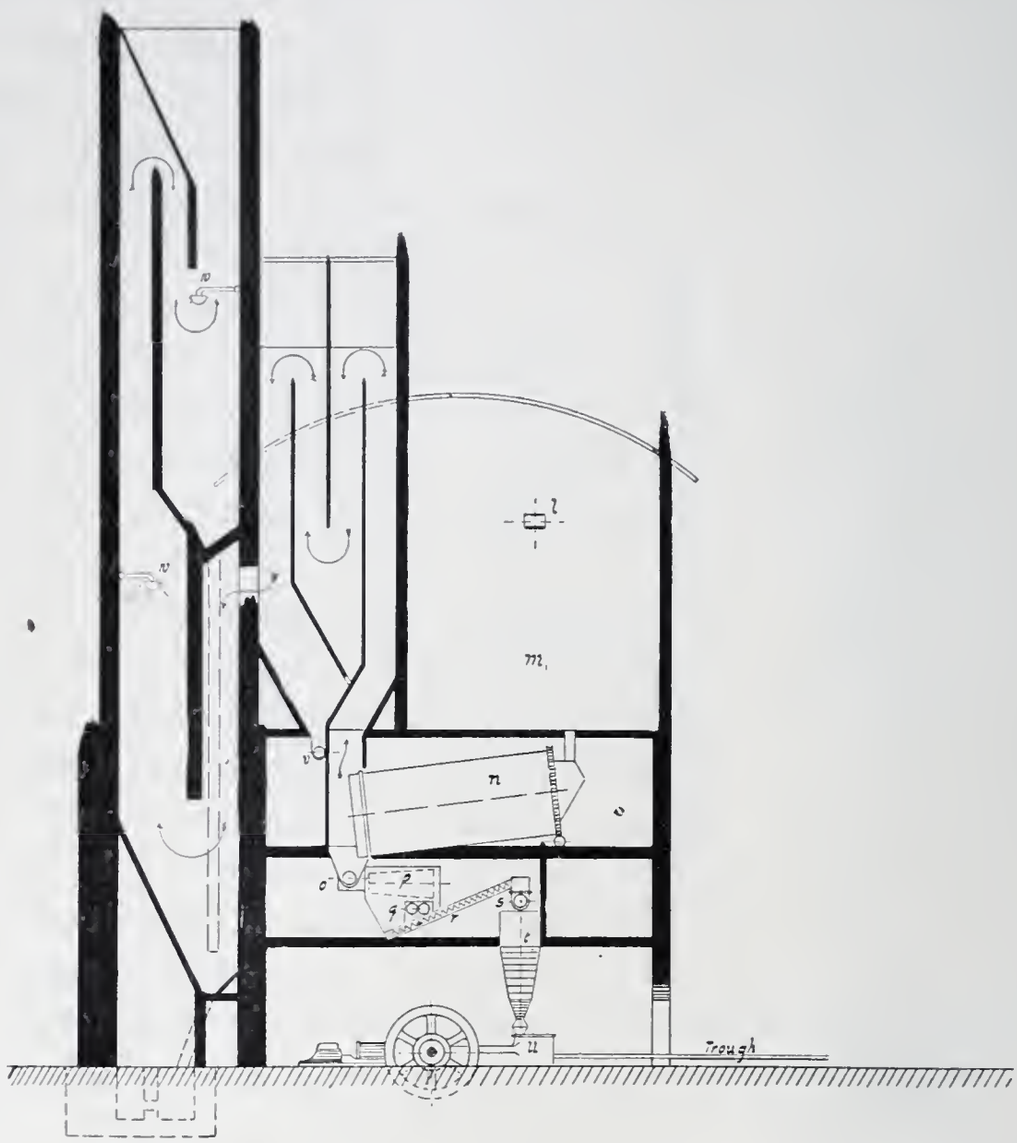

Fig. 3.

the output of coal amounts to 360 tons per day, and the raw coal contains 59.1% water, nearly 770 tons of material have to be handled in the way described besides the coal for the boilers, and it is therefore necessary to store during the day the amount of "knorpel" and boiler coal required during the night. This is done in a large bin (m, Fig. 3) which occupies the whole length of the boiler house. Immediately below these

bins are the drying apparatus (n), each consisting of a large steel cylinder of about 10 ft. diameter and 23 ft. long, closed at both ends by perforated steel plates, in the perforations of which are fixed 343 tubes of 4 in. diameter and open at both ends, like the tubes in a boiler. The cylinders are slightly inclined and rotate at a speed of 5 r. p. m. round a hollow axle through which the heating steam enters. The coal falls from the bin into the tubes and, due to the inclination and rotation of the apparatus, rolls slowly down, each part of it coming in contact with the hot tubes, and at the lower end falling into a spiral conveyor (o). The condensed water of the heating steam is caught by two water traps at the circumference of the cylinder and leaves through the hollow axle again for the boilers with a temperature of about 265° F. Each drying apparatus is driven with a belt drive and worm gear by a 7.5 horse power motor situated in the small room immediately below the upper end of the cylinders. For heating purposes the exhaust steam of the presses and the steam engines of the electric generating plant is used together with a certain amount of saturated steam taken directly from the boilers, the pressure of which has been reduced to 27 lbs. per square inch. The temperature of the steam entering the apparatus is 370° F. at the pressure just named, so it is slightly superheated. Before condensing, the steam has to deliver the following amount of heat:

1. The temperature of the coal proper has to be raised from 41° F. (in winter time) to about 230°. With an output of 300 metric tons, or 793,000 lbs. of briquettes, containing 13% of water, per day of 24 hours, there has to be heated about 28,700 lbs. of coal proper 189° every hour, and assuming the specific heat of the coal as 0.24 we want 0.24 x 189 x 28,700 =1,300,000 B. t. u.

2. The water in the raw coal has to be warmed from 41° to 230°, and as the coal contains 59% of water, there are $\frac{28,700 \times 59}{41}$=41,350 lbs. of water requiring:

$$189 \times 41,350 \times 1.0224 = 8,000,000 \text{ B. t. u.}$$

3. The briquettes contain 103,000 lbs. of water; the raw coal contains 993,000 lbs. of water. The difference, or 890,000

lbs. per day, has to be evaporated, involving a consumption of heat of

$$37{,}100 \times 951 = 35{,}250{,}000 \text{ B. t. u.}$$

4. The air that passes through the drying apparatus has to be heated. As it passes first on the outside of the apparatus it is warmed to 77°, containing 0.1% of water at this point. Behind the apparatus it contains about 23.1% of water at 181° F. For the hourly evaporation of water we want therefore $\frac{37{,}100 \times 100}{23}$ or 161,000 lbs. of air, the heating of which requires $0.24 \times 161{,}000 \times (181-77) = 4{,}020{,}000$ B. t. u. So we get a total delivery of heat of 48,500,000 B. t. u. per hour. As the heating area of each apparatus is $343 \times 23' \times \frac{4}{12} \times 3.14 = 8{,}250$ sq. ft., all six apparatus therefore equaled 49,500 sq. ft., and as the medium temperature of the steam is $(370+266)\ \frac{1}{2} = 318°$ F., and of the air and coal passing through the tubes 138° F. we get a medium coefficient of transmission of heat of $\frac{48{,}570{,}00}{(318-138)\ 49{,}500} = 5.45$ B. t. u. per hour per square foot per degree difference of temperature. This value seems very high. Mr. K. Krumbiegel, the engineer of the Lauchhammer works who made these determinations, advances the theory that there is no transmission of heat from superheated steam, the superheated steam probably evaporates the condensing water in entering the apparatus, and only after its saturation does the transmission of heat take place. For the maximum capacity of the drying apparatus it would not matter whether we used superheated or wet steam; only the amount of steam to be consumed would be changed. Decisive for the use of superheated steam was the smaller loss in the pipes from the boiler house to the press house, amounting to only 0.068° per ft. The amount of air that passes through the apparatus has to be so great that it can receive all the water expelled from the coal without getting oversaturated. This volume of air is drawn through the apparatus by the natural draft of the stacks. They are 115 ft. high and directly behind the drying apparatus. As the mixture of steam and air that is drawn out contains a considerable amount of very fine coal dust, which would be a great annoyance to all the neighbors as well as a considerable loss,

the "brazen," as this mixture of air, steam and coal dust is called, has to pass up and down through quite a number of passages before discharging into the atmosphere. There, due to the changes of direction and to the condensation of part of the steam on the dust particles, they cannot follow the gases, so fall into the helical conveyor (v) at the bottom of this dust catcher. As it is impossible to catch all the dust by this so-called dry separation, in some of the following passages a number of sprinklers are arranged, injecting fine sprays of cold water into the "brazen," by which the dust is removed almost completely. The dust laden water is led through clearing tanks where it is allowed to settle, and after it has become dry is fired under the boiler. In this way the "brazen" is cleaned so that a clear white steam leaves the stack, much to the advantage of the Lauchhammer plant over many others where you can always see a thick black cloud hanging around the stacks.

The dry coal is collected by a helical conveyor (o, Fig. 3) which transports it to a rotary sieve. The great mass of it passes this sieve and falls directly into the transverse conveyor (r), but part of it passes first between a last pair of rolls by which the few large pieces that are left are broken up. The transverse conveyor (r) empties into another helical conveyor (s) which distributes the material to the hoppers (t) over the presses. Through these hoppers pass a number of triangular passages connected with the stacks, the suction of which produces a strong draft throughout. This is necessary in order to cool the "knorpel," for if it is too hot in entering the presses the briquettes will be of inferior quality. At the time I was in the Lauchhammer works they were preparing designs for an additional cooling apparatus between the drying apparatus and the presses.

The presses consist essentially of a steam driven plunger pressing the coal dust through a conical mouth-piece against the resistance of the briquettes already made. This mouth-piece is formed by two plates of chilled iron, the inclination of which is regulated by a screw so that the pressure required

for pressing the briquettes varies from 17,000 to 22,000 lbs. per square inch, this being the pressure by which the coal dust or "knorpel" is formed into briquettes. It seems that the sudden rise of temperature due to this enormous compression softens the bitumen in the coal, and this hardens at once at the water-cooled sides of the mouth-piece, in this way forming a hard, weatherproof briquett. But as this pressure is only required for a very small fraction of the forward stroke of the plunger, the steam pressure on the piston of the press engine is stored during the rest of each cycle in two very heavy fly-wheels. The stroke of the plunger is 8⅝ inches. The presses are fed during each return stroke from the hopper by a pair of rotating rolls, cooled thoroughly by a steam exhauster. The cylinders of the steam engine are 20 in. diameter and 25.5 in. stroke; the superheated steam entering the cylinders at a pressure of 120 pounds per square in. and a temperature of 464° F. With 110 r. p. m. each press makes from 60 to 70 metric tons of briquettes per day. The briquettes are pushed directly by the plunger through long narrow troughs, made up of strips of flat iron, to the loading place several hundred feet distant, either into a bin or directly into cars. Each press requires about 120 horse power, but this increases as the size of the briquettes decreases.

The exhaust steam of the presses is used for heating the drying apparatus. It is therefore no wonder that the consumption of energy per i. h. p. is only 3,100 B. t. u., which means an efficiency of about 80%, while for the ordinary engine 12 or 13% are considered high. Power is to be had very cheaply at briquetting works, and nearly all plants I know of are connected with large electric generating stations, the exhaust steam of the engines being used for heating the drying apparatus. At Lauchhammer they use electric power not only for the motors in the briquetting plant, but also for many other motors in the bridge works, in the foundry, for general lighting purposes, etc. Other briquette works sell their surplus of electric power to the towns and villages in the neighborhood.

The steam required is generated in a boiler plant of 11 two-flue boilers with 1,025 square feet of heating surface each and carry 128 lbs. pressure. Each boiler is connected with a

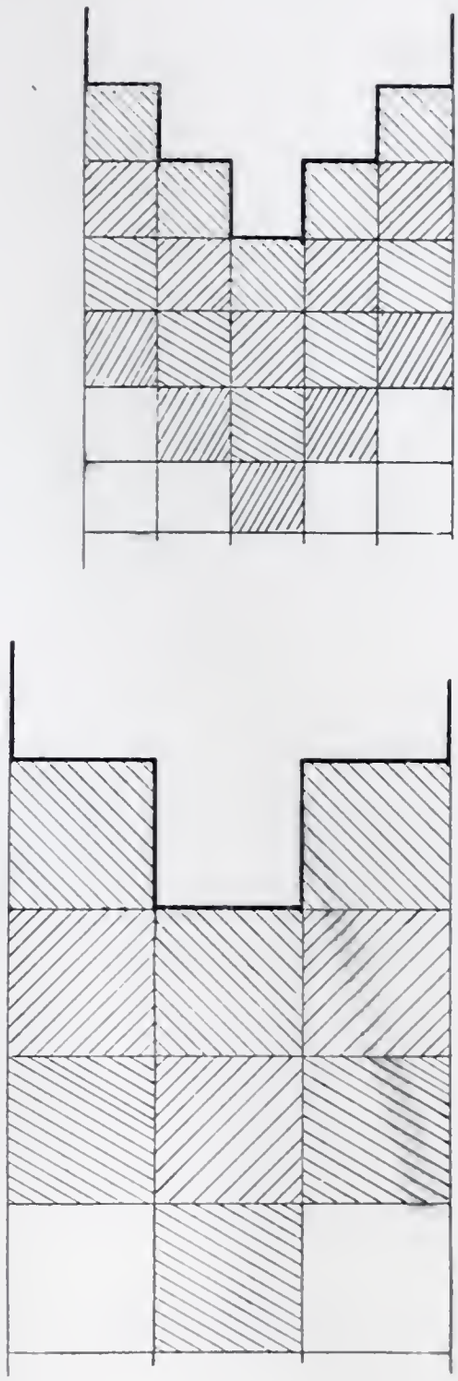

Fig. 4.

superheater, enabling them to superheat the steam to 570° F. The boilers have stepped grates and are fed automatically from the coal bins above, only raw coal and the dust from the settling tanks being used for their fuel. The power is very

cheap, the cost of 1 kilowat being less than 0.85 cents per hour.

Briquettes are made in several different sizes. The so-called Goliath briquette is 8¼ inches long, 3 inches wide and 2 inches thick, and has a weight of about 1.75 lbs. The standard or household briquette is 7½ inches long by 2⅜ inches by 1½ inches and weighs about 1 lb. For boiler firing they make the so-called industrial briquette, cubes of about 2½ inches, and for gas producer works there are nut briquettes, cubes of 1½ inches. Of these latter forms 3 or 5 are made with each stroke of the plunger which has the stepped shape shown in Fig. 4. This is necessary to prevent the cohesion of the briquettes, the parallel hatched areas indicating the briquettes made at one stroke. The plunger has engraved on its front the trade name or mark of the briquettes and this appears on each briquette in raised letters at the front and depressed letters at the back. You can observe on the specimens the bright shining surface of the briquettes on the five sides where it has been in contact with the cold metal plunger and the mouth-piece, only the back side being dull where it has been in contact with the briquette made by the previous stroke. The following analyses show the great increase in heating value of the briquette over raw coal:

	Raw Coal	Briquettes
C	26.12%	55.56%
N+O	10.97%	23.33%
H	2.02%	4.30%
S	0.22%	0.47%
Ash	1.57%	3.34%
Water	59.10%	13.00%
Effective heating value,	3,600 B. t. u.	9,000 B. t. u.

In many tests of ordinary boiler firing extending over several weeks they have got an evaporation of 6 lbs. of water per pound of briquettes. They are an almost ideal fuel for boiler firing as they give almost no slag at all, the ash being

a loose light yellow powder. At Lauchhammer they have equipped some boilers with a water filled ash pit; the hot ash falling into it evaporates part of the water and as the steam passes through the grate it prevents almost completely the formation of slag. But the fact alone that slag is formed shows how high the temperatures are that may be reached with this fuel. Another great advantage of the briquettes is that they make almost no smoke.

The price of briquettes was, two years ago, $1.80 per ton, but this can be lowered considerably, for many works paid dividends of 20% to 30% and even higher.

I will not close without mentioning the one disagreeable thing connected with the manufacture of briquettes. This is the mass of dust developed. Though the whole machinery is completely enclosed, the whole plant and its immediate neighborhood would be completely covered with a thick layer of fine coal dust, if it was not frequently removed. This dust is a little dangerous, as it has a strong tendency to spontaneous combustion, and it can start a bad fire which cannot be fought by the ordinary means of throwing on water with a hose, for the fine burning dust would fly around and spread the fire rapidly. The only way to extinguish it is to flood the whole building and put out the burning or rather glowing dust by wet pieces of cloth. Especially in the passages for the dry separation of the dust from the "brazen" are explosions by spontaneous combustion of this dust liable to occur, and there are at the tops of these passages great explosion gates of about 100 square feet for each system, that open rapidly if there is a dust explosion.

I owe sincerest thanks to my former colleague, Mr. Fladrich, of Lauchhammer, for the valuable aid he has given me in preparing this paper and sending these specimens exhibited here.

DISCUSSION.

S. M. KINTNER, Member—Would it not be feasible to use the coal which Mr. Muellenhoff states is too heavy, on account of excess of water, to ship to advantage, to generate steam at the place and transmit power electrically. There might also be possibilities of generating producer gas and then electrical transmission.

K. A. MUELLENHOFF, Member—We were not allowed to use a current for power transmission of a higher tension than 2,000 volts, so the scheme was not practicl.

S. M. KINTNER, Member—I do not doubt that the very great limitation of voltage was the point that acted against the transmission electrically. In this country we transmit 100,000 volts or higher if we wish.

S. DIESCHER—The question of briquetting coal is a very important one. We have no lignite, but it would pay not only to use our slack but to crush lump coal for briquetting. This briquetted fuel having lost its tendency to cake and bake will make no more smoke than anthracite does, and, as cheaper fuel is applicable to all purposes, would be an efficacious preventative of the intolerable smoke nuisance. If our bituminous coal was first washed 75% of the acid it contains could be eliminated, and then briquetted it will stand shipping anywhere and be in great demand.

In Mexico they are using briquettes brought from Wales. I have several times urged the Pittsburgh Coal Company to go into the briquetting business, but they said they got enough for their stock now. I say they could at least get lump prices for the briquettes.

As it is now, even with automatic stokers, the pressing of boilers beyond their capacity makes smoke.

K. A. MUELLENHOFF—There are large deposits of brown coal in Arkansas, in the Dakotas, in Montana and also a

deposit in Vermont. In Germany, France and Belgium they grind enormous masses of coal and then briquette it with the addition of 5% of pitch. These briquettes are used extensively on many railroads for locomotive firing. In using raw coal there is always much loss by breakage and the fine coal falling through the grate. That is avoided by using briquettes.

Of briquetting plants, there have been several in this country, but so far as I know they have all been forced to give up after a short time. Only one has been successful, at San Francisco. Briquetting of slack or crushed coal was described in a paper published in the Journal of the Association of Engineers of January, 1906, and there was also a very extensive description in the Transactions of the American Institute of Mining Engineers of February, 1904. But there are only a few remarks on the briquetting of lignite.

F. Z. Schellenburg, Member—I doubt about the lignite of Vermont, but in Michigan they are making briquettes out of the peat taken from the black bogs.

H. C. Babbitt, Member—What are the amounts of volatile matter and fixed carbon in brown coal?

K. A. Muellenhoff—The carbon is 55.6%. The analyses I could get made no distinction between fixed carbon and volatile matter.

H.C.Babbitt—There should not be as much loss of smoke in burning our coal as with the European coal, because our coals are all fat in volatile matter while the European coal rarely has any volatiles that run over 20%.

Samuel Diescher—At what temperature is the coal compressed?

K. A. Muellenhoff—I guess it is about 130° F. After it leaves the press water falling on it will evaporate. In the press itself the temperature is estimated as high as 700°. F.

F. I. Ellis, Member—Some years ago we made a test on a distinctly brown coal that had much of the lignite forma-

tion. We tried it in a furnace uncompressed, but were very much disappointed at the results, for after it had been in some time you could pick it up with a handkerchief and not burn your hands. The coal we pressed with an ordinary screw did somewhat better and we also pressed some in a brick machine, which did better still. However, the whole thing was a disappointment and we gave up the question of burning brown coal.

K. A. Muellenhoff—I suppose you used an ordinary brick press where the material is forced to the mouth-piece with an ordinary helical screw. This kind of briquett contains so much water that in burning it is first necessary to heat the water and volatilize it, and so of the little fire that is in the briquette nearly all the heating value is absorbed in drying and keeping the combustion process going.

Experiments show that bituminous coal that is pressed into briquettes with the use of some binder will not give smoke. I do not know if this behavior is due to the presence of a certain percentage, 5%, or 7% to 10%, of volatile matter, but the fact is it gives practically no smoke.

Samuel Diescher—This condition is due to a physical cause and not to a chemical cause. It is in this, that the gas is developed just at the rate at which it is consumed, whereas you take raw coal and throw it into a grate and the gas blows out from the center of the lump with a considerable pressure. This is due to the greater density of the briquette.

F. Z. Schellenberg—It appears that the specific gravity of this briquette is less than our coal, but that must come from the lower ash. Our density here is 1.25 and I understand the briquette is 1.19.

In the lignite mines of the West they cannot use their own coal in the blacksmith fire to get a welding heat; they have to import coal to run their forges.

Our lignites in the West have 20% of water and upwards.

K. A. Muellenhoff—I have never heard of using lignite for blacksmith purposes or any other direct metallurgical

uses. But we used it at Lauchhammer to a large extent for making generator gas, and nearly the whole plant was run with gas made from these briquettes.

F. Z. SCHELLENBERG—Is it used for smelting?

K. A. MUELLENHOFF—I believe not. It contains too much sulphur, and the briquettes are not hard enough to stand the pressure. In our cupolas we used coke.

The larger the briquette the less the cost of manufacture. The small briquette costs about 1½ times as much per ton as the large briquettes, and if you were to give a manufacturer an order for 10,000 tons of the large size or 20,000 tons of the small size, I guess he would take the smaller order for the large briquettes, because there is a greater profit in them.

F. Z. SCHELLENBERG—Another advantage is that they are safe from spontaneous combustion, the storage of them is very favorable in space as against raw coal, and there is less loss by abrasion.

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*COMPRESSED AIR.

ITS PRODUCTION, TRANSMISSION AND APPLICATION.

† LUCIUS I. WIGHTMAN.

Non-Member.

If there is truth in the saying that old age commands respect, compressed air certainly has strong claims for respectful consideration, for its past reaches far beyond the beginnings of recorded history. It is not a great stretch of the imagination to picture the primeval savage, in a canoe hewn from a log with a stone axe and shaped with the aid of fire, sailing over the streams and inlets of prehistoric lands under the impulse of the wind caught in a rude sail of skins stretched on a crude wooden framework. But this is a practical age and this is a company of very practical men; and in such a place these imaginary pictures have no place.

* Meeting Mechanical Section, May 1, 1906.

† 11 Broadway, New York.

Coming now to facts, there can be no doubt that air compressed in some degree found practical application in the very earliest ages of man's history. The reduction of metals from their ores was one of the earliest arts acquired by mankind; and the blast furnace must have been the basis of these processes. Just what form these primitive compressors had must be very largely a matter of conjecture. But no doubt their prototypes are found in the appliances still used by savage tribes. Among these may be mentioned the "wind bag" of skin, trodden by the feet, and the wooden box and movable piston, the original of the modern air compressor; and the simple, modest little bellows of the fashionable fireside of today is doubtless but little different from those used on the hearths of the most ancient homes.

Heron—or Hero—of Alexandria may perhaps be considered the individual pioneer in air power development. The earliest authentic records of compressed air are found in the "Spiritalia" of this old philosopher. He himself must have had some means, other than the common bellows, for producing the pressures required in operating "Hero's Fountain," which is a feature of all the text books on physics.

The priests of ancient Egypt largely owed their sway over the credulous people to their understanding of the more elementary properties of air. Their supernatural phenomena—so-called—are easily explained today by the most simple laws. The miraculous opening of the temple doors when a fire was lighted on the altar was caused simply by the expansion of a volume of air under the heat of the altar fire, this expanded air displacing water from a tank into a suspended bucket, so connected by rollers and cords as to open the doors by its weight. When the fire went out, the doors closed—most supernaturally, to be sure—by a reversal of this process. By the same means did the famous statue of the god Serapis move, on proper occasions. And the awe-inspiring vocal statue of Memnon at Thebes owed its divine voice to the expansion and contraction of an air volume under the heat of morning and the cool of evening.

Hero himself—probably the first "hot air" artist—knew of a means of compressing air by the fall of water in a tube—a precursor of the modern hydraulic compressor. Pliny later mentions a similar device. Ctesibius, a famous Alexandrian engineer of about 120 B. C., invented "wind guns" capable of discharging projectiles. To him must be awarded the palm as the first to produce and apply high pressures.

But these are historic curiosities. Passing on rapidly, in the darkness of the early Christian era and of the Middle Ages, compressed air seems to be lost. It reappears again in the writings of Lord Bacon, who describes a diving bell. Then come the records of achievement of Halley, Smeaton and Brunel, in England, and Von Guericke in Germany. Papin, about 1653, devised a compressed air system involving compression in a water-wheel-driven pump and transmission through a tube to a distance. He also experimented with a pneumatic parcel dispatch. His attempts failed through ignorance of the fundamental physical properties of air.

The latter part of the eighteenth century and the early part of the nineteenth mark the real birth of air power. During this period Medhurst, the great Danish engineer working in England, laid the foundations of present pneumatic practice. He produced and transmitted pressures of more than 200 lbs., and applied them in motors; he developed a practical, though not economical, system of pneumatic dispatch for parcels and persons; he built the first pneumatic automobile in 1800; and he otherwise contributed richly to pneumatic science. Compressed air as a distinct and recognized branch of engineering may be said to date from this period; and under the mechanical renaissance of this time, developments were rapid. The experiments of this time foreshadow, in diversity and daring, the great achievements of today. Pneumatic locomotives and motor cars were built and operated. Pneumatic dispatch systems achieved a practical success in London in 1845. America was not behind the old world; and Dr. Gorrie, of New Orleans, built the first refrigerating plant in 1850 and

laid the principles upon which rest the tremendous refrigerating systems of today.

Mann, in 1829, suggested and patented a system of stage compression with intercooling. But he lost a splendid opportunity to win an immortal name in science by his failure to develop his ideas; they lay dormant for almost half a century. The great Alpine tunnels of the early 70's gave a tremendous impulse to pneumatic development. Sommeiler, on the Mont Cenis bore, used hydraulic compressors. Later developments in this tunnel work brought water piston compressors, with injected jets or sprays for cooling; and pneumatic locomotives were used for haulage in these great bores. The Hoosac tunnel in America first brought the pneumatic rock drill into prominence; and since that time the genius of Burleigh, Ingersoll, Rand, and Sergeant has produced the modern rock drill—probably the greatest single epoch-making device, after the steam engine, in history.

This historical sketch, brief as it is, is convincing proof that compressed air has a legitimate claim to dignity and consideration. It has ceased to be a novelty; it has passed the experimental stage. It is today a recognized industrial necessity, firmly established as one of the accepted indispensable factors in modern progress.

Engineering science universally recognizes three general subdivisions of any power system. First of these is the power producing or generating element, which is, in essentials, a converter of energy from some present form into another form more convenient, more adaptable to the purpose in hand. The efficiency of this element depends upon the reduction of losses in conversion to a minimum. The second sub-division is that of the power distribution or transmission element, by means of which the converted energy is delivered to the point of application. Its efficiency also depends upon the reduction of all incidental losses. Third among these sub-divisions is the power application element, which must also be looked upon as an energy converter, with an efficiency determined by the extent of the conversion losses. This, in brief is the

scheme of analysis to be followed in this paper; and, that modern practice may be the better understood and followed, each sub-division will be opened with a very brief discussion of the theory involved.

COMPRESSED AIR PRODUCTION.

The fundamental principles of compressed air production, or air compression, are contained and expressed in the two Primary Laws of Gases. For, though air is not a perfect gas, it approximates this ideal nearly enough to meet the requirements for all practical purposes.

The First Law of Gases—independently enunciated by Boyle and Mariotte and variously known by their two names—states that, at constant temperature, the volume of a gas varies inversely as its pressure; or, its temperature remaining constant, the product of volume and pressure in a gas is a constant. Regnault, by later experiments with most refined apparatus, found that this law was not strictly true, discrepancies appearing at very high pressures. But for practical purposes its relations may be accepted as correct, as follows: and different temperatures.

$$P_1 \ V_1 = P_2 \ V_2 = P_3 \ V_3 = K$$

the constant, K, having different values for different gases and different temperatures.

The Second Law of Gases, variously known as Charles' or Gay-Lussac's Law, states that at a constant pressure the volume of gas is proportional to its absolute temperature, or, in more practical form, at constant volume the pressure of a gas is proportional to its absolute temperature. Expressed in equation form,

$$V_1 \ (T_2 + 459.2) = V_2 \ (T_1 + 459.2)$$

the constant 459.2 being the absolute zero Fahr.

The conditions of practical air compression are not fully covered by either of these laws alone. For, as a matter of

fact, pressure, temperature and volume vary simultaneously in compression, and the relations must be expressed in an equation of three variables and combining both laws, as follows:

$$P_1 \ V_1 \ (T_2 + 459.2) = P_2 \ V_2 \ (T_1 + 459.2)$$

Bearing in mind these three fundamental equations, the phenomena of air compression may now be considered.

Compression, or an increase in the density of a body of air, is invaribly accompanied by an increase in temperature. This increase in temperature is wholly independent of the rate or means of compression. It is a phenomenon inherently characteristic of the compression process, and is the direct result of an increased molecular activity in the air. The temperature attained is a function of the degree of compression; but the factor is not a constant, being largest in the early stages of compression and decreasing as the higher pressures are approached. It is a fundamental law of physics that the production of heat demands an expenditure of power; and the power consumed in producing heat in air compression is lost, so far as the inherent economy of compression is concerned. But in actual practice, this heat might be made use of. In one notable air power plant, the heated water from jackets and intercooler was led to the feed-water heater and in this way there was at least a partial recovery of the lost energy. The degree of heating of jacket water depends largely upon its rate of flow over the heated surfaces; and if any attempt is made to use this heated water for boiler feed, there is a fine problem in determining the exact point beyond which the economy ceases to be a virtue. For in a desire to secure hot jacket water, the efficiency of compression may be sacrificed.

This heat of compression is productive of other evils which can—in degree at least—be obviated; and the efforts of compressor designers have from the very first been directed toward this end. In the path of every pneumatic engineer loom two guide posts; the one points the way to economy and

success—the other marks the path to disappointment and failure. The first is isothermal compression—the second is adiabatic compression.

Isothermal compression is a visionary process in which the heat developed in compression is removed as fast as produced and is, therefore, harmless. It would be a realization of Boyles' law, in the expression of which—$P_1 V_1 = P_1 V_2 = K$ the factor T does not appear. Though the best air compressors of today closely approximate its values, isothermal compression cannot be fully realized, for a perfect cooling system is not known and, so far as can be seen at present, never will be.

Adiabatic compression, on the other hand, is a grim and forbidding reality—a compression process in which all of the heat developed is retained. It represents the two Primary Laws of Gases in combination; and its expression, involving the three variables of pressure, temperature, and volume, has been already stated, but will bear repetition:

$$P_1 V_1 (T_2 + 459.2) = P_2 V_2 (T_1 + 459.2).$$

There is a slim consolation to be derived from the fact that adiabatic compression, too, cannot be wholly realized; for no perfect heat insulator is known. But this fact brings more sorrow to the heart of the scientific investigator than to the practical engineer.

Assuming for a moment that it were possible to compress a volume of air isothermally, and remembering that the product of pressure and volume under this condition will remain constant, it is seen that when the original volume has been reduced one half, the pressure attained must, therefore, be twice the original. But practice rudely shatters these theoretical assumptions. For, as a matter of fact, it is found that the pressure is doubled before the volume is reduced one half; and a very decided rise in temperature is noted. Consideration of these facts forces the conclusion that a part of the work of compression was expended in producing the rise in tempera-

ture noted; and, furthermore, it becomes painfully evident that this heat increment of work is, so far as the compression process is concerned, wholly lost. In other words, when the air during compression is allowed to heat itself, more power is required to produce a given volume at a given pressure than would be necessary if it were possible to keep the air cool throughout the process. In the first case, there would be adiabatic compression; in the second, isothermal compression. This is a very brief, very elementary statement of the phenomena which give rise to the problems which have confronted the designers of the modern air compressor.

It will have been seen from the foregoing brief discussion that the fundamental problems of pneumatic science are thermo-dynamic in character. The production of heat in compression is unavoidable. The solution of these basic problems, therefore, lies in the removal or neutralization of this heat of compression before it can have any effect on the air volume. This cannot be done completely, since no perfect and instantaneous cooling device is known. Scheme after scheme has been tried and found wanting, until today two general systems alone survive and are accepted by the designers of compressed air machinery. In combination, they attain the nearest approach to the ideal which, as has been seen, is isothermal compression.

First of these two—by right of seniority if not of effectiveness—stands jacket cooling. The barrels and—in the best air compressors—the heads of the compression cylinders are surrounded by a water space or jacket through which an adequate supply of cold water circulates, the waste water carrying away that portion of the heat of compression which is conducted from the air volume through the metal walls. A possible use of this heated water has already been suggested. Water jacketing is useful, but not adequate. It is useful; first, because it prevents the cumulative effects of the heat of compression which would quickly destroy all lubricants and result in injurious expansion strains in the metal of the machine; second, because it keeps the temperature of the air admission

passages and valves low, thus admitting cooler air to the cylinder—and every reduction of 5° in intake temperature is equivalent to an increase of 1% in compression efficiency. Water jacketing is not adequate; first, because air is a poor heat conductor and though the outer film in contact with the cylinder walls is cooled, the heat from the interior of the air volume remains; second, because the advancing piston continually covers up more and more of the cylinder walls and the cool area exposed is continually reduced until, just when the highest temperature is attained at point of discharge, only a small fraction of the total cooling surface is in contact with the compressed air. The jacketing of cylinder heads as well as barrels in the best compressors of today improves but does not wholly obviate this defect.

The second accepted system of cooling is that secured by stage compression. In this arrangement, instead of being confined to a single cylinder (or parallel duplex cylinders), the compression process is subdivided between two or more cylinders. In the first and largest, air at atmospheric pressure and temperature is admitted and compressed to a moderate pressure and temperature. This compressed air is discharged into an intercooler where its temperature is reduced, by circulation over and contact with water-cooled surfaces, to almost that of the cooling water—perhaps really lower than atmospheric temperature. From the intercooler, this cool and moderately compressed air enters a second cylinder and is compressed to a higher pressure. In a two-stage compressor, this completes the process; in three and four stage machines, the process is continued in a third, or a third and fourth, cylinder. Correct design so proportions the cylinder diameters that the load on all pistons is equal and the maximum temperatures in all cylinders should under such conditions be approximately the same, since this is a function of the number of compressions and not of the initial pressure.

It may be said in passing that in the early days of pneumatic science a third system of cooling was tried—the injection of water in a spray into the compressing cylinder

in front of the piston. It may be interesting to note here that this was one of the first types of compressors built by the Ingersoll Rock Drill Company—one of the originals of what is now the Ingersoll-Rand Company; and some of these old machines are still in use today and doing good work. Their compression economy was as high as, if not higher than, that of the most refined modern types. But they were costly machines. The presence of water in the cylinders enforced a low piston speed and, to secure any great capacity, a machine so large was required as to offer serious objection to their wide adoption. Moreover, the proper regulation of the injection of cooling water under varying loads was a delicate problem. Practical difficulties were found to more than offset their high efficiency, and the type was discarded.

Returning to the question of stage compression, the success of the multi-stage system of air compression depends more upon the efficiency of the intercooler than upon any other one thing. For the primary object of stage compression is the reduction of the power required. There are other advantages which will be mentioned later, but at this point a comparison of the gains by compounding will show strikingly the economical advantage. Assume a volume of 100 cubic feet of free air which is to be compressed to a pressure of 100 lbs. gauge. Were perfect isothermal compression possible, this would require 13.17 horse power to accomplish the work indicated. Average single stage compression, which may be considered as practically adiabatic will call for 18.0 horse power. Two stage compression will demand 15.4 horse power; three stage, 14.6 horse power; and four stage, 14.2 horse power. As compared to isothermal, then, the efficiency of single stage compression in this case is 73.2%; of two stage, 85.5%; of three stage, 90.2%; and of four stage, 92.7%. These are purely theoretical considerations. As a matter of fact, two stage compression should be used in this case. For, while theoretically there is undeniably a higher saving in three and four stages, the added complication of design in the increased number of cylinders, valves

and working parts, with complex coolers, might so increase frictional losses as to offset the gain; and it would certainly add to cost of maintenance.

The experience of the best builders of compressors has determined the following limits for pressures in different stages; single stage, up to 100 lbs.; two stage, 75 to 500 lbs.; three stage (straight line), 500 to 2500 lbs.; three stage (duplex), 500 to 1500 lbs.; four stage, 500 to 3000 lbs. The real difference in economy between three and four stage compression is often so small as to make a choice difficult. As a general rule, it may be said that three stage straight line compressors should be used for comparatively small capacities; for moderate and large air capacities, its balanced features and its ready adaptability to steam compounding recommend the duplex type. A three stage duplex will still require four cylinders, hence the process might as well be divided into four stages, with no increase in working parts.

The design of these high pressure machines offers peculiar difficulties. While the temperatures attained are not excessive, the great reduction in volume has made the problem of adequate cooling unusually difficult. But before considering this specific phase of the subject, it will be well to take up the general subject of intercoolers.

The successful intercooler, looked upon simply as a heat-removing element, involves several important considerations. It must provide for a very complete subdivision of the air volume, that internal heat may be dissipated with as little reliance as possible upon the heat-conducting properties of the air itself. It must present an adequate cooling surface to this subdivided air; and it must provide for a circulation of cooling water not only rapid and free, but also properly directed in relation to the flow of air. The first two considerations are met by the same means, viz., by the use of a nest of tubes through which the water flows, and over, about and between which the heated air circulates. Properly disposed baffle plates enforce the travel of the air back and forth across, instead of merely along, these tubes. The air must be outside,

not inside, the tubes; otherwise each tube will contain a column of air, only the outer film of which will be cooled, the interior retaining its heat. The third consideration is met by causing the air to flow in the opposite direction to the water. This is found to give higher efficiency and greater rapidity of heat absorption. A fourth consideration ought also to be mentioned, as effecting the thermal efficiency of the intercooler. This is the necessity for ample cross-section in the intercooler passages, that the travel of the air may be slow and the contact with cooling surfaces prolonged. Some modern compressors, while having plenty of cooling surface, have the tubes so closely bunched and the intercooler shell so small that the air velocity in transit destroys the thermal efficiency.

Considerations merely mechanical in the correct design of an intercooler are none the less important. Expansion and contraction must be provided for; otherwise there results either a leakage of air and a proportionate waste of power, or a leakage of water into the air chamber, which may be carried over into the next cylinder. This suggests a very important point, viz., the proper drainage of the intercooler. The lowering of the temperature of the air condenses the entrained moisture. If this is not removed at proper times, it will accumulate over the lower tubes, reducing the cooling area as well as the air passage. But the greatest danger is that this accumulation of water will be caught in the sweep of air and carried over in a mass into the high pressure cylinder; and a broken cylinder head, bent piston rod, or other disaster will result.

Evidently such an intercooler as has just been described, while perfectly suitable for two stage compression, or even three where the air volume is large, is not practical with the small air volumes involved in the later stages of high pressure compression, particularly in machines of small capacity. But long experience and good engineering have solved the problem with success. The method adopted is the complete submersion of the intermediate and high pressure cylinders in water

boxes filled with circulating cold water. In this way every inch of metal exposed is a cooling surface; valve caps, air heads, ports, and cylinder walls—all are kept cool, while intercylinder cooling is secured by novel devices. It will be enough to describe one which experience and careful test have shown to be most effective and efficient—the "annular space" intercooler. It consists of two concentric metal cylinders, as thin as the pressure will permit. Their difference in diameter is such as to leave a thin annular space between them, through which the heated air from the intermediate cylinder must pass, spreading out in a thin film between two cold metal walls. The coldest entering water is discharged in the interior of the inner cylinder, and flows thence into the water box in which the intercooler, as well as the compression cylinders, is immersed. The discharge pipe from the intermediate cylinder to the intercooler is entirely submerged, itself acting in some degree as a cooler.

High pressure compressors are no longer "freak" machines, unreliable and largely experimental. The increasing use of high pressure air has demanded a solution, once for all, of the problems of high pressure compression; and the pneumatic engineer has been equal to the task. The best thousand pound pressure compressors of today are as reliable, as efficient, as thoroughly "standard," as the lower pressure machines.

It was mentioned earlier in this paper that there were other advantages than increased economy to be gained by compound or stage compression. They are well worthy of consideration in their effect upon ultimate economy and will be briefly discussed here.

The mechanical structure of a machine must be adequate to the maximum strain upon it. This predetermines the minimum amount of material in it. But the endurance of that machine depends upon its factor of safety; and good design demands that this be kept large, with the minimum amount of metal used. In other words, while the maximum strain must be provided for, the average strain must be kept well below the maximum, if the machine is to operate well under long

and continuous service. Compound air compression reduces the structural strains in the compressor, resulting in a higher factor of safety and longer life for the machine, with a given weight of metal. In a single stage compressor, the piston starts against no resistance but rapidly builds up a pressure to terminal maximum; and this is maintained until it is instantly relieved by the opening of the intake valves. A 24-inch piston compressing to 100 lbs. gage, single stage, encounters a total resistance of 45,239 lbs. or nearly 23 tons; and at 90 r. p. m. this is encountered and relieved 180 times each minute. It will take the best of metal and plenty of it to stand up under such service as this. But let this same work be done in two stages. The maximum pressure on the low pressure piston will depend upon the cylinder ratios. The pressures in the high and low pressure cylinders will, moreover, partially balance and equalize; and it is found that as a matter of fact, the maximum strain in the machine is reduced to only 55 or 60 per cent of the maximum in single stage compression —in the example cited, from 4140 "ton minutes" to 2277 or 2484 "ton minutes." These are impressive figures and suggest almost unlimited possibilities in the way of improved operation and longer life. This difference in pressures is felt not only in the machine structure, but also in the valves, which must always be considered the most vulnerable, as well as most vital, detail of the compressor. But— and here is a vital point too often overlooked by the designer—this maximum strain of 4140 ton minutes must still be provided for in the machine structure. For the momentary failure of cooling water supply, or the breaking of a high pressure discharge valve may at any moment throw this full high pressure load on the low pressure cylinder. When this happens, in a compressor designed only for compound strains, there is nothing to be done but sit down and figure the damages. The engineer or manager contemplating the purchase of a compound compressor will do well, when it comes to a comparison of prices, to figure the comparative costs per unit weight; and, other things being equal, he should give his order to the builder of the heavier machine,

whose price, figured on this basis, will not seem so unreasonably high. But there are, unfortunately, builders who, alive to this fact, give list weights on their machines higher than strict honesty would permit; and the only safety for the buyer is in the insertion of a penalty clause in his contract, based on the actual net weight of the compressor. This will protect him against over-enthusiastic and imaginative manufacturers.

Another advantage of compound compression lies in the improved steam economy if the machine is steam driven. The conditions just cited in the previous paragraph explain this. It was seen that the terminal strain on the machine, and therefore the terminal power required, was reduced by compounding 55 to 60 per cent. Manifestly this permits a lower mean effective pressure in the steam cylinder, secured by a shorter cut-off, since the power required at the end of the stroke is so much reduced. More of the work of "passing center" may be entrusted to the energy of the fly-wheel, instead of being provided for by a late cut-off. The mechanical features already mentioned permit also a higher piston speed, improving the steam economy by reducing leakage and condensation losses.

Compounding the compressor also has an important bearing on the volumetric efficiency of the machine—a fact which is due to three causes. As effecting volumetric efficiency, the clearance in only the low pressure or intake cylinder need be considered. In the single stage machine, clearance air at end of stroke may be at a pressure three or four times that which exists in the intake cylinder clearance of a compound compressing to the same pressure; and on expansion it will occupy a proportionally larger portion of the cylinder, before free air can enter. Further than this, the terminal temperature is lower in the compound intake cylinder than in the single stage. Cylinder heads and walls, valves and ports are thus kept cooler, and the incoming air is not so much heated. Further, leakage past pistons and valves is less in the compound than in the simple machine, since the difference in pressures is less.

At this point a slight digression may be permitted. The indicator diagram of an air cylinder is a reasonably accurate record of pressures; but it is wrong to base any estimate of volumetric capacity upon the air card. When the inlet valves open, air rushes into the cylinder and fills it. If the air enters through heated ports, it is itself heated and expanded—and the volumetric capacity of the compressor is accordingly reduced. There is too pronounced a tendency toward valuing a compressor by the card it shows. This is but one of the ways in which an apparently excellent card may in reality hide a true state of affairs directly opposed to high economy.

It may be almost unnecessary to suggest the advantage of compounding in its relation to improved lubrication and, to this extent, in its effect upon the life and operation of the compressor. The terminal temperature in a cylinder being a function of the number of compressions in that cylinder, the high temperatures of single stage compression may result in the charring of the lubricant into a gritty or gummy substance which, accumulating in valves and passages and on cylinder walls, results in excessive friction, added power and lowered efficiency by leakage.

Still another gain by stage compression is in the dryer air delivered by the compound machine. It developed in the discussion of the intercooler, that that device, properly designed and drained, was an effective air dryer and moisture trap. But it is only one link in the system of withdrawing water entrained in the air. The importance of removing the moisture from compressed air is becoming more generally appreciated under the present tendency toward larger units, and longer and more complex air transmissions. In long pipe lines carrying large volumes of air, moisture, if present, will accumulate in the low places in the line and will ultimately fill the pipe, shutting off the passage until the air pressure forces the water up and overcomes the resistance. The writer, in going over the pipe line of a large contract plant in Pennsylvania, was attracted by a periodical rush of water through the 8-inch pipe. Following the line to the next low place, he found a 1-inch

drain pipe. Opening this, it took eight minutes by the watch to draw off the accumulated water, which had been rushing up and flowing back repeatedly. Yet he was assured by the foreman that that place had been drained less than two hours before. The plant in question was made up of single stage compressors, with no coolers whatever. Aftercoolers would have prevented this trouble.

Now, this illustrates a point of vital importance in its bearing upon transmission line efficiency. Going further, to the machine using the air, it is unnecessary to dwell upon the trouble and delay caused by the freezing up of exhaust ports, due directly to the presence of moisture in the air. Occasionally the builders of compressed air machinery meet a situation which forces them to the belief that the real cause of freezing at drills and air motors is not fully appreciated. There is often a mistaken idea that it is the atmospheric temperature which causes this. On the contrary, the writer has seen rock drills freeze tight at midday in the torrid August sun of central New Mexico. The fact of the matter is that the cold is produced directly by the expansion of the exhaust air. It was seen that the compression of air, by a molecular action, produces heat. The exact reversal of this molecular action, in expansion, produces cold. Naturally the trouble is exaggerated in winter weather. But if the moisture is removed from the air before expansion, no air motor can freeze up however high the degree of expansion, for the very simple reason that there is nothing to freeze. In a great quarry plant of northern Ohio, rock drills are operated in the open air with the thermometer far below zero, with not even a suggestion of vapor at the exhaust. But the compressor intercooler is not wholly adequate to this problem of air drying. At best it can remove only a part of the moisture in the air. There must be some further arrangement for air drying; and this leads naturally to a discussion of aftercoolers.

The aftercooler is in essentials identical with the intercooler. Its efficiency is determined by the same conditions; in fact, in compressors of duplex type, the intercooler and after-

cooler may be identical in design and capacity. Aside from removing the evils of water in the transmission line, with increased frictional resistance and liability to freeze up in winter; and aside also from avoiding the trouble with "frozen" air motors, the use of an aftercooler is important in its effect upon the life and operation of the motors themselves. Water is not a good lubricant; equally axiomatic is the fact that oil and water will not mingle. The actual fact is that the delivery of water to a drill or other air motor washes out the lubricant, increasing the wear and reducing its effectiveness. Especially true is this in the case of pneumatic tools, where a light lubricant is used. The use of moist air in an expansive engine is practically impossible—a fact largely responsible for the ill-repute of the air motor. Complete aftercooling makes this possible in many cases.

Of value no less important in the air power system is the effect of aftercoolers upon the transmission line efficiency. Nothing will destroy air plant efficiency more quickly and effectively than a leaky pipe line; and nothing is so conducive to a leaky line as wide extremes of temperature, with consequent large strains of expansion and contraction. Without an aftercooler, air from the compressor enters the pipe line hot; the line itself is cold. There is an immediate expansion which extends along the line with continued operation. Now, when the air plant is shut down—probably at night—there is a corresponding contraction all along the line. There needs no voice from the tomb—or elsewhere—to dilate upon the resultant difficulty in keeping tight joints and preventing leakage, even with the best mechanical precautions in the line. The aftercooler is not a luxury; it is an economical necessity in the high-grade air power plant.

The Cleveland Stone Company, at their quarry at North Amherst, Ohio, have an air power plant which is probably without a peer as an example of refined pneumatic engineering. The transmission lines in this system aggregate miles in length and the power is used in drills, channelers, pumps, hoists, mill engines and steam shovels. While reheating is now employed

on all but the drills, it was not originally used; yet the engines were for some time worked on short cut-off, and in the midst of a cold winter no trouble was experienced with freezing of lines or motors. The remarkable result is explained by the exceptional precautions taken to provide dry air; and a brief description of the methods employed may not be out of place here.

In the first place, the air enters the compressors through "air washers," which enforce its passage downward through tubes and then upward in bubbles through a body of cold water. This removes from the air the all-pervading dust and grit of the quarry, and incidentally dries it somewhat by lowering its temperature and condensing some of the moisture. Leaving the low pressure cylinder, the air passes through an intercooler, thence to the high pressure cylinder and thence to an aftercooler. From this it goes to very large primary receivers from which the transmission lines radiate; and at intervals along the lines are secondary receivers set *below* the pipe grade. Moisture is first withdrawn from the air in the "washer;" and then in turn in the intercooler, the aftercooler, the primary receivers, and the secondary receivers. The result is the delivery of absolutely dry air to the motors and maximum pipe line efficiency under all weather conditions, though the lines and the machines are all out-of-doors and unprotected.

More remarkable still, the miles and miles of pipe line have not a single leak. On the contrary, they hold working pressure over night; they were installed under a guarantee to hold full pressure for twenty-four hours. Much of this, of course, is attributable to fine workmanship and studied design. But more than these is it due to the uniform temperature maintained by the use of efficient aftercoolers, with consequent freedom from excessive expansion and contraction strains.

The foregoing discussion of cooling appliances is a digression from the logical line of thought. Returning now to the question of compound compression, the writer asks permission

to quote from his paper on that subject in "Power" for January, 1906.

"It will not do to reason that a compound compressor, simply as a compound, is more economical than a high class simple machine, for such is not the case. On the contrary, only compounds of the highest class are advantageous from an economical standpoint.

The gains depend, not simply upon stage compression and effective cooling, but also upon correct design throughout the machine and a consistent attention to every detail. Every condition which may possibly affect the air from intake to discharge must be properly considered and provided for. Some of these defects which may offset compression economy have been mentioned. But their importance merits a brief repetition of them here; a weak structure and insufficient bearings (based on a mistaken idea of reduced strains) with no provision for unexpected contingencies, resulting in excessive friction losses; multiplicity of wearing parts, absorbing a large portion of the power theoretically saved; heated and restricted air passages, inefficient valves, neglect of proper jacket and head cooling; frugal and ineffective intercoolers; poor workmanship, resulting in leakage losses. Not only may these defects largely offset the saving by compression in stages, but it is a fact that compounds now on the market may (and do) require more power per cubic foot of air compressed than well designed, high class, simple compressors of equivalent capacity."

There followed, in the paper in question, a report of a series of tests made upon machines of two representative builders—several compounds of one maker (who was designated as "Maker B.") and some single stage and compound machines of another maker (distinguished as "Maker A"). For complete details of these tests reference may be made to the paper in question. Let it be enough to say here that the conditions in all cases were as nearly identical as possible, and that the tests were made upon machines which had been in actual service for from two to fourteen years, except in the

case of the compounds made by the builder of the single stage compressor; these were new machines. However, this does not invalidate the argument, since the comparison is primarily between single and two stage machines. Briefly, the results of these tests may be summed up thus:

In relation to volumetric efficiency, Maker A's compounds showed an average efficiency of 94.7%; his single stage machines, an average of 88.2%; Maker B's compounds, an average of 84.76%. Maker A's compounds, therefore, suffer an average loss of theoretical capacity of only 5.3%; his simple compressors, a loss of 11.8%, while Maker B's compounds lose 15.24%. of their theoretical capacity. From this the conclusion is enforced that, in these instances, Maker A's correct design and high grade workmanship effect an average saving in compound types of 9.94% and in single stage types of 3.44%, as compared to Maker B's machines of inferior construction.

Considering now the question of compression efficiency, Maker A's compounds averaged 92.06% efficiency; his simple machines, 82.98%, while Maker B's compounds showed an average of 75.14%. Maker A's compounds lose 7.94% of the power applied; his single stage compressors, 17.02%; while Maker B'c compounds waste 24.86% of the power applied. It appears from this, then, that superior design and workmanship give Maker A's compound engines a superiority of 16.92%, and his simple machines, that of 7.84%, over the compound compressors of Maker B.

It may be stated here that the above compression efficiencies of the single stage machines are referred, for more ready comparison, to perfect two-stage compression. Their average efficiency referred to perfect single stage compression is 95.12% —a truly remarkable performance; departing less than 5% from theoretically perfect action.

In closing this discussion of compound compression, the writer again asks to be permitted to quote from the paper above referred to:

"The term 'compound' or 'two stage' as applied to air compressors should properly stand for superior economy. The

buyer of a compound rightfully expects a saving by its use. The foregoing tests, taken without prejudice from average machines in ordinary practice, indicate how even reputable builders, acting no doubt in all good faith, may furnish a compressor which may prove a veritable 'gold brick' in the hands of the trusting purchaser. Poor practice may prove the undoing of the best theory. That compressor only is a commercial and economical success which embodies a sound theory in a mechanical structure correctly designed, built by skilled and careful workmen, and so simple as to be readily understood, handled and maintained by mechanics of average intelligence."

Coming now to consideration of the mechanical design of air compressors, it is found that accepted practice divides these machines into two great fundamental classes—straight line and duplex. The changes which can be rung on variations of these two designs are almost infinite. But analysis will reveal a difference only in detail. The basic principles upon which the designs rest are the same in all.

The straight line air compressor may be considered the pioneer type. The term "straight line" is one of the happy expressions of mechanical phraseology, for it carries with it its own explanation. Its fundamental and distinguishing characteristic is the fact that power is directly applied to resistance. This at once implies simplicity, lack of complication, absence of many parts with undue power consumed in friction. All this results in a machine of high mechanical efficiency and reliability under continued hard service. Its simple design renders it especially attractive for conditions which afford only unskilled attendance. There can be no more sturdy and dependable compressor than the good modern straight line. The compressors examined in the tests reported above belonged to this class; and the figures there set forth show that this type leaves little to be gained in volumetric efficiency. This is a condition, moreover, which is practically constant at all speeds. The main difficulty with the straight line compressor develops in the steam end.

Variable cut-off steam valves give good steam economy at or near normal speed. But the inherent characteristic of the design—the direct opposition of power and resistance—produces conditions which offer serious objections to the straight line machine under widely varying load. In the cylinders, steam pressure falls as air pressure rises; and the flywheels must be relied upon wholly to carry the machine over dead center. This is all very well at high speeds; but reduced load calls for a reduced speed, else there will be a total waste of power by the escape of air at the relief valve. At low speed the energy in the flywheels is not sufficient to pass the center, if the cut-off is short. Cut-off cannot be automatically varied with load, as in a Corliss machine; and to avoid entire stoppage on light load, either the cut-off must be lengthened to give sufficient power to pass centers, in which case there is a waste of steam when the machine speeds up under returning load, or there must be a fixed point below which speed must not fall, in which case there is a blow-off of compressed air at all loads below this limit. These facts force the somewhat unpleasant conclusion that the straight line compressor is not economically self-regulating at less than 35 or 40 per cent of full load.

This condition practically forbids the successful compounding of the steam end of a straight line. For the high expansion, which is the secret of compound economy, only exaggerates the difficulties at fractional loads. The "double-compound" straight line compressor is practically a constant-speed machine, its economical cut-off admitting of no variation. At normal speed it gives good economy; but underloaded the waste of air at the relief valve simply offsets its normal advantage.

But the straight line compressor is not to be wholly condemned. It remains today—and justly so—the most popular machine for plants of moderate capacities using moderate steam and air pressures and working under fairly constant loads. These are the very conditions characterizing the majority of cases in which compressed air is used; and they are con-

ditions in which high steam economy is less important than moderate cost and thorough-going reliability.

The second great class of air compressors is that broadly designated as the duplex type. This is not the place for a minute investigation of structural strains and theoretical considerations. For the present purpose it will perhaps be best to look at the duplex compressor as simply two straight line machines set side by side and coupled up for mutual assistance. Seen in this light, the duplex is found to possess all the advantages of the straight line, with the addition of some very important superiorities distinctly its own.

The first of these superiorities lies in the matter of regulation. Quartered cranks permit one steam cylinder to help the other when it most needs assistance; and, a quarter of a revolution later, this favor is reciprocated. The arrangement admits of no "dead center;" and a good duplex will run so slowly at highest loads as to barely turn over, speeding up instantly, however, with increasing load. Best of all, it does this without any change of cut-off; and whether the speed be high or low, steam is always used economically.

But it is as a "double-compound" compressor that the duplex stands without a peer; for in all probability high steam expansion in compound steam cylinders will effect a saving three or four times that secured in stage compression. In the first place, either steam or air end can be compounded without any increase in the number of parts. More than this, the reciprocal cylinder arrangement secures the full advantage of compounding *over the entire load range.* The fact—peculiar to air compressors—that the load per stroke is constant regardless of speed makes a "double-compound" air compressor as completely self-regulating as a simple machine. There will be a slightly increased condensation at lower piston speeds; but the fact that friction loss is a function of the speed and diminishes with it, introduces a saving about offsetting the increased condensation loss at low speed. For these reasons the steam consumption of a double-compound duplex is very nearly proportional to its load.

As compressed air enters more and more largely into industrial activities, the size of plants and units increases, and the demand for economy grows more imperative. It is this condition of affairs which is bringing the duplex compressor into ever-increasing prominence and popularity. It is recognized as distinctly the machine for high grade permanent plants of moderate or large size, using modern high steam and air pressures, operating under widely varying loads and under conditions which make economy of fuel and water essential.

An extended discussion of the subject of air compressor valves is out of the question in such a paper as this. Volumes could be written upon it. It will be enough here to briefly review the essentials of a correct air valve. It may be safely left to the intelligence of the audience to draw just and adequate conclusions as to the merits of any particular valve they may have in mind.

The air intake valve will logically receive attention first. Briefly, its functions are, to admit the full volume of clean, cold air to the cylinder with the least expenditure of power; to keep this air in; and to maintain this performance indefinitely. Analysis of this general statement will develop the facts sought. First, the valve must admit the full volume of air; this demands an instantaneous and complete opening, automatically timed to prevent the escape of air already compressed, and short, direct and unobstructed ports and passages. Second, it must admit clean air, calling for a design which will admit of connection for drawing the air from a place free from dust and grit. Third, the air admitted must be cold; this is partially met by the arrangement necessitated by the second consideration; but more than this, the cold air must nowhere be heated in transit, demanding valves, ports and passages cooled by the jacket water and never called upon for the discharge of the hot compressed air. Fourth, all this must be accomplished with the least possible expenditure of power—a condition demanding few parts and perfect adjustment. Fifth, this valve must keep the air in, calling for automatic

and complete closing at just the right time, with perfect seating to avoid leakage. Sixth, it must maintain this performance indefinitely, hundreds of times per minute, demanding simplicity and strength, fine workmanship, and the very best materials.

Similarly, the functions of the air discharge valve are, to release the full volume of compressed air from the cylinder with the least expenditure of power; to keep it out; and to sustain this service indefinitely. This statement also may be analyzed for the essential facts. First, the release of the full air volume calls for automatic timing of an instantaneous and complete opening, and full, free, direct discharge passages. Second, this must be performed at the least cost for power, necessitating few parts and proper adjustment, that friction may be low. Third, the valve must keep out the air it discharged, which means that it must close instantaneously and completely to a perfect seat at just the right time. Fourth, the continued maintenance of this performance demands simplicity of design, strength of parts, materials of the best quality, and fine workmanship.

It will be noted that the essentials of the successful intake and discharge valve are practically identical, the only difference lying in the necessity for admission of *cold* air through the former. This fact forbids the admission and discharge of air through the same passages. Furthermore it demands that intake and discharge passages shall be separated as far as possible.

It is unnecessary to enter into any extended investigation of the steam end of the steam-driven air compressor. The best engine practice is, broadly speaking, the best compressor practice. But there are conditions in air compression which, in relation to compounding the steam end, seem often not to be well understood.

When steam cylinders are to be compounded it is essential, in order to attain full advantage of expansion, that the cut-off be maintained almost constant at the point fixed by the ratio of the cylinders; for any great change in the cut-off will

derange the expansion ratio and prevent the economy sought. Now, in customary engine practice which demands a constant speed, load variations are met by shifting the cut-off; and with light loads the condensation loss due to excessive expansion will make the net saving by compounding questionable, to say the least. Especially is this true where the engine runs non-condensing, and for this reason small and medium sized engines are seldom compounded. But in a correctly designed air compressor of duplex type, governing is done in just the reverse manner, viz., by maintaining a fixed cut-off at point of highest economy and varying the speed automatically with the load. The reasons, therefore, which usually decide against compounding (particularly in small and medium-sized plants) where the steam pressure is low or condensing is not practicable, do not hold with air compressors.

When a new plant is to be installed, including boilers, these can be made for 125 lbs. steam pressure at very little added cost; and this is a very good pressure for compounding. But that peculiar condition of air compression just described, viz., *constant load per stroke regardless of speed,* makes compounding advantageous and economical, all things considered, with boiler pressures as low as 90 lbs. non-condensing, or 75 lbs. condensing. Where boiler water is scarce or costly, or of a bad quality, the reduced amount of feed water required may be an added argument in favor of compounding. While where new boilers are to be installed, the smaller boiler equipment permitted by this reduced steam consumption will partly offset the small added cost of the "double-compound" compressor. Cut-off of one half in compound cylinders will give the same expansion as cut-off of one quarter in a non-compound; and it is easy to see that this fact gives to the compound advantages wholly in addition to mere economic gains, in the reduced load on valves and valve mechanism, reduced leakage, diminished clearance evils, lowered condensation losses, improved lubrication, and diminished wear and tear.

In all this it is to be remembered that compressor practise is unique in that while the speed varies with the load, the

load per stroke remains constant at all speeds. Power, therefore, remains constant per stroke, and all the advantages outlined above are fixed in their values regardless of load.

The regulation of steam driven compressors need not be discussed here. The methods employed are too well known. But the principle, whatever the device employed, is the same in all—a variation of speed to change the displacement to meet varying demands for air. But when some other power than steam is the prime mover of the compressor, other means of governing must be used. And this leads naturally to the subject of power driven air compressors.

The power driven air compressor is essentially a constant-speed machine. Since its actual piston speed and therefore displacement cannot be changed, the only means of adjusting the volume of air compressed to the demand lies in making ineffective a portion of the displacement. But evidently economy forbids blowing off superfluous air through the relief valve. There are three general methods of "unloading" a compressor. One is by opening, at light loads, a passage from the intercooler to the atmosphere, discharging the low-pressure air until load is resumed. This is simply a waste of power—yet better than blowing off high pressure air. Another method is by automatically holding open one or more discharge valves at both ends of the air cylinder, which balances pressures on both sides of the piston and removes all but the friction load. This is a very complete and positive unloader—and therein is its only objection. If the unloaded piston is traveling under balanced pressure of 100 lbs. on each side, and load is resumed at any point of the stroke, on the return stroke the piston must displace a full cylinder of air at 100 lbs.; in other words, the load during this return stroke is three or four times the normal maximum. This overload, moreover, is instantly thrown on the piston, held throughout a stroke, and is instantly relieved; and this sudden, positive assumption and release throws strains on the machine structure which limit the use of an unloader of this type to compressors of comparatively small capacity. The third method of regula-

tion is by limiting or varying the compressor intake—and this comes very near being a solution of the problem. Receiver pressure controls a valve in the free air intake, throttling it when load is light, opening it as load increases. An oil damping device makes the unloading and loading gradual and perfectly safe in all capacities. But this device is not without its draw-back. As the intake is throttled, the air admitted to the cylinder becomes rarified, and on return stroke, though the free air volume is small, the range of pressures is so much increased that terminal temperatures may soar to destructive heights. This style of unloader, therefore, is not wholly adequate where the load variation is very great; and the difficulty increases with the terminal pressure.

In the regulation of the power driven air compressor plant, less reliance must be placed upon the automatic regulation of the individual machine than upon the intelligent subdivision and management of the plant itself. The old-time truism about the folly of putting all the eggs in one basket has become so polished by use that it is today really a gem, nowhere more apropos than in the modern pneumatic power plant with power driven units. At the outset it must be remembered that the power driven compressor has no overload capacity, i. e. an overload of volumetric capacity or piston displacement. In the installation of a plant made up of these units, therefore, the maximum capacity must be provided for in the normal output of the machines. Yet fractional loads must also be provided for; and here the designer is confronted with another inexorable condition, viz., the power driven compressor unit is a constant-speed machine.

In may be remarked here that in 90% of the installations of power driven compressors, either electricity or water power will be the prime mover; and of these, probably 80% will be electric driven and the remainder water driven. It will be safe to consider the case of the electrical compressor as typical, since the deductions will apply almost equally well to those driven by water motors.

The electric motor has its maximum efficiency under continuous running at its full load rating. Below that, efficiency falls away. Plant economy, therefore, forbids underloading the electrical compressor unit to any great extent. But in all probability the load curve of the plant will vary widely. Since the individual unit cannot be relied upon for economical regulation, the only solution of the problem lies in the sub-division of the plant into units, of suitable capacities to be determined by the character of the load. This sub-division should be such that the greater variations could be provided for by cutting out one or two or more units, the others meanwhile continuing to run at or near full load. A theoretical case may best illustrate the principle.

Assume that the problem is to install an electrical air power plant which is to work under load variations of from 500 horse power maximum to 75 horse power minimum, with a normal of 400 horse power. The proper solution, in order to get the best economy possible, would be the installation of three motor-driven compressor units; two of 200 horse power and one of 100 horse power. The smaller unit would have an automatic unloader, preferably of the third type mentioned. The possible combinations of this plant would be 100, 200, 300, 400 and 500 horse power, under all of which the motors and compressors would be running at maximum efficiency. When the load fell below 100 horse power the unloader would safely and economically care for a reduction of 25 or 30%. Such a plant could be made very largely automatic by the use of automatic relay starting-and-stopping controllers, in which the governing valves are adjusted to work in proper rotation under slightly different variations of pressure.

This in briefest outline is the system of unit plant design. It requires an intelligent adjustment of operating conditions to smooth out the load curve as far as possible. But it offers a full solution of the problem of economical management of a large power driven compressor plant under varying load. This is a point at which electrical and pneumatic practise meet;

and the difficulties involved are well worthy of the best talent in both lines of engineering.

The gas engine driven air compressor is today largely an unknown quantity. In small units, for portable work or other purposes requiring only small capacity, it has been successfully built and operated. But in large sizes it is still largely in the experimental stage. The problems involved seem not to be beyond solution, and they are already well understood. But there has not been enough demand for this class of machines to develop an experience which can be safely relied upon. If, as is sometimes said, the gas engine is the prime mover of the future, it behooves the pneumatic engineer to face the problems of gas engine compression. But as yet the occasion has not arisen; and pneumatic engineers today find quite enough to occupy their attention in other lines.

The second of the three general divisions adopted in this paper comes now for discussion.

THE TRANSMISSION OF COMPRESSED AIR.

The theory of compressed air transmission is not elaborate or complex. In fact, the theory itself is beautifully simple. It is in its practical application that difficulties are encountered, and they are both complex and troublesome. In general it may be said that compressed air is governed by the ordinary laws of the flow of gases. It has been seen earlier in this paper that an aftercooler must be considered an essential part of the up-to-date, efficient air power plant. When it is used, the air is delivered to the pipe line cold. But whether an aftercooler be used or the air delivered direct to the line, the heat in the air is quickly dissipated; and for all practical purposes the transmission of air is isothermal, i. e. at constant temperature. Any loss of pressure in transmission (assuming there is no leakage) will be due entirely to frictional resistance in the pipe. The law governing this loss cannot be stated exactly. Attempts almost without number have been made to establish the exact relationship of values, but each has given a different result. One of the simplest, and one perhaps just

as accurate as any of them, is expressed algebraically thus:

$$D^p = K \frac{V^2 L}{d}$$

which may be transposed into the form of a rule as follows: The drop in pressure in a transmission line varies directly with the length and the square of the velocity, and inversely with the pipe diameter. But the exponent of the velocity is found to vary and the square is correct only for moderate velocities. The constant K is a mantle of charity thrown in to cover the multitudinous ills depending upon the degree of smoothness of the pipe interior, the number and angle of bends, the number of valves, etc., etc.

Perhaps sometime in the dim and shadowy future a genius will arise who will determine exactly the relations of pressure, temperature, volume, velocity, cross-section, configuration and length, with some decisive values for the constant describing the physical properties of the line itself. But at present an intelligent approximation is the best that can be expected. By a pardonable stretch of the imagination, the aftercooler may be considered a part of the compressed air producing element; at least discussion of it under that head makes it unnecessary to refer to it again here. With this granted, the air power transmission system may be considered as made up of the air receivers and the pipe lines.

The compressor discharge is essentially pulsating in character. The air receivers are "rectifiers," so to speak; they receive and absorb the pulsating impulses and deliver a steady flow of air to the line. They are also, in small degree, accumulators, in which excess energy is momentarily stored and may be momentarily drawn upon. But it does not pay to rely too much on this source of power. In a broad sense, the air receiver is a balance wheel in the pneumatic system, equalizing supply and demand and smoothing out the minor fluctuations in the load curve. There cannot be too many air receivers, nor can their capacity be too large, *provided they do not leak*. Many small receivers are better than one large one.

They all have a certain cooling value and are useful in removing moisture which passes the intercooler and condenses in the pipe line. Preferably they should be scattered along the line, located at low points and *below* the line, so that water will flow from the pipe into them. It is almost unnecessary to say that they should be properly drained.

As to the transmission line itself, not much can be said. First of all, the cross-section should be determined by some of the numerous formulas; and then ten per cent may safely be added for good will. It should be laid so that it *will not leak*. More money can be lost through a few seemingly insignificant leaks in the line than can be saved by the utmost refinement of compound steam and air cylinders. Wide-angle bends are preferable to elbows. The pipe interior should be kept free from obstructions. The line should be properly supported for its whole length, so that its joints will not "spring" with its own weight. Expansion and contraction should be provided for either by slip joints or, better, by off-sets of about a pipe length at reasonable intervals. Every low place should have a drain and *must be drained*. A line on the surface is better than one buried; a leak is more easily discovered and stopped. Valves should be of gate pattern, as offering less resistance; and rising-stem valves have the advantage of showing at a glance the degree of opening. A leak is one of the unpardonable defects in an air transmission system; and its avoidance is purely a question of workmanship and careful attention to the details just mentioned. A pipe line which will not hold gauge pressure for twelve hours cannot be considered wholly a success; and there are contractors who are ready to install systems of any magnitude whatever under such a guarantee.

A scheme of air transmission which is sometimes practicable and advantageous is that known as the "loop system." Its name perhaps describes it sufficiently. For supplying power to scattered machines in a limited area, as in a quarry, it has the advantage of giving maximum pipe area, positive assurance against complete breakdown, and the means of

repairing, altering or extending any part of the system without crippling or interfering with the other parts.

Another scheme of transmission having a limited application but an unquestionable advantage is the "return-pipe" system, in which the exhaust from the machines using air is piped back to the compressor intake. This is almost an ideal transmission, in which the compressed air is a power transmitter pure and simple, with no inherent friction. The system is highly efficient. It eliminates entirely the clearance losses, often enormous where air is applied to an old steam engine or pump. It gives more power from a given cylinder, because the mean effective pressure is greater. But its chief economy lies in the efficiency of compression. The greatest losses in compression occur in the first stages and the lower pressures. For instance, it takes the same power to compress a given volume of air from atmosphere to 30 lbs. gauge as from 30 lbs. gauge to 90 lbs. gauge. In the first case, discharging into the atmosphere, 30 lbs. effective pressure could be applied on a piston. In the second case, discharging at 30 lbs. and piping the discharge back to the compressor, 60 lbs. effective pressure could be had on the piston. The difference is even more striking at higher pressures. The power required to compress a volume of air from atmospheric to 60 lbs. gauge will compress it from 60 lbs. gauge to 350 lbs. gauge. These pressures, applied in an open and in a return-pipe system, will yield 60 lbs. and 290 lbs. effective pressure respectively. This merely suggests possibilities. It must be freely confessed that the phenomena of compression do not fully cover the case. This full economy cannot be made available at the motor. But the return-pipe system cannot be adequately discussed in so general a paper as this. It does show, however, an unquestionably superior efficiency when the conditions are right for its adoption.

The double pipe line required by the return-pipe system will cost little, if any, more than the single pipe of the open system, because of the smaller size required. Such leakage losses as may occur can be made up by a small "booster"

compressor. The return-pipe system of air power transmission is one of the inviting subjects for investigation awaiting the development of more general application. It has not yet received the recognition it deserves. Yet the well known "Return-Air" pumping systems depends for its superior economy upon this very principle, and is in successful operation in a hundred plants. The new "Electric-Air" rock drill is a miniature application of this principle.

The logical development of the scheme of this paper brings attention at this point to the discussion of the third division.

THE APPLICATION OF COMPRESSED AIR.

The phenomena of air expansion are governed by the same laws as those of air compression. Boyle's and Gay-Lussac's Laws of thermo-dynamics express the relations of pressure, temperature and volume. In fact, the theory of the application of compressed air may be best understood by considering expansion simply as a negative compression process. Isothermal expansion is expansion at constant temperature, i. e. no heat is lost. It is an impossible ideal, whose value can at best be only approximated. Adiabatic expansion is expansion with a total proportionate loss of heat; and it, too, can be only partially realized.

Were isothermal expansion possible, the expansion of a given quantity of air to one half its original pressure would give a volume just twice as large as the original. As a matter of fact, in practice the volume will not be doubled when the pressure is reduced one half. For the expansion, reversing the molecular action of compression, results in a lowered temperature which contracts the air volume, according to Gay-Lussac's Law.

As, in adiabatic compression, there is a loss as compared to isothermal due to the *positive* heat increment of work, so, in adiabatic expansion, there is a loss as compared to isothermal due to the *negative* heat increment of work. There is, therefore,

in adiabatic compression and expansion a double loss of energy. It was shown that the loss in compression can be reduced, but not wholly avoided, by removing the heat of compression as fast as produced. So, in air expansion, the loss may be diminished, but not obviated, by "removing the cold," i. e. by heating the air during expansion. With this elementary theoretical sketch, the subject of reheating may be taken up.

Evidently it is impossible to heat the air in an expansive engine *during* expansion. But the same effect may be secured by heating the air before it enters the cylinder, thus giving it an excess initial pressure such that the expanded volume will be normal and at normal pressure. If heating is carried only to this extent there is no positive gain, but simply an avoidance of an otherwise inevitable loss. But this is by no means the limit of the possibilities of reheating.

Gay-Lussac's Law states that, at a given pressure, the volume is proportional to the temperature; which means that reheating is equivalent to an increase of volume at that pressure. Or, looked at from another view-point, reheating a given volume of air will increase its pressure. In either case, reheating results in a positive increase in the available energy of the compressed air.

With single cylinder or duplex air engines, preheating only is practicable; and it results in securing the same mean effective pressure in the cylinder with a greater degree of expansion and therefore with a greater economy of air. But compound air engines, such as may be used on pumps or hoists, permit both preheating and interheating. This is "stage expansion" and is the exact reversal of "stage compression."

The limit to which reheating may be carried seems to be fixed only by the endurance of the materials exposed to the high temperatures; more especially, by that of the lubricant used in the engine cylinders. But where an oil of high flashing-point is used, the temperatures which may be applied are surprising; for while the initial temperature may be very high, the wide range of expansion results in a mean cylinder temperature which is within reasonable limits and wholly practicable.

The reheating of compressed air offers the most inviting field for pneumatic research today; and it is a field which is only beginning to be explored. Facts and figures are singularly hard to get hold of. While many types of reheaters are on the market, the wide variation in capacity ratings shows that even the builders are not at all certain of their ground. But there is an awakening in progress. All other pneumatic appliances are nearing the limit of mechanical and economical refinement. Compressed air is reaching out beyond the small mine or shop plant into the vast field of general power transmission on a large scale. The rock drill and pneumatic tool do not use air expansively, nor is their mere air economy a fair measure of their value. But for pumping, hoisting and general industrial use as a motive power, in units of any capacity, expansion must be employed if any degree of economy is sought. The great companies who are today the leading exponents of air power are alive to the requirements of the situation. Their engineers are grappling with the problems of reheating with the same skill and energy which have been brought to bear along other lines of pneumatic development. When compressed air reaches a condition of advancement where the very highest economy of application is essential, the builders of air power machinery will be ready with reheaters of the same reliability and efficiency which mark the other pneumatic appliances of today, placing them in a class distinct and unique among the mechanical developments of the past hundred years.

It was suggested to the writer that in this paper there be embodied a comparison of compressed air and electric power. But an evening could be devoted to that subject alone without doing it justice. It may be said, however, in closing, that the rivalry between compressed air and electricity is more imaginary than real. A few years ago, perhaps, each viewed the other with suspicion. But in this age of tremendous industrial development and inexorable sifting-out of non-essentials,

all things worthy of survival find their proper place. It has been so with compressed air and electricity. Each has a field distinctly its own, into which the other can not hope to enter with any prospect of success. At points these fields touch or even overlap; but even here, instead of bitter rivalry, there is a mutual recognition and a cordial co-operation.

When compressed air and electricity *do* join forces, the result is apt to be spectacular, from an engineering standpoint. Where can be found a greater masterpiece than the electro-pneumatic switch and signal system of the New York Rapid Transit Subway, in which the electric current throws the valve admitting the sturdy power of compressed air from automatic air compressors driven by electric motors? Or what can be more striking, more simple or more absolutely dependable than the storage air brake system of the St. Louis Transit Company, in which the air from automatic electrical compressors controls the electric cars which carried the hundreds of thousands of World's Fair passengers without a mishap, a breakdown, or a delay? A hundred other instances might be cited in which air and electricity—either powerless without the other—have joined hands in a wonder-working achievement; and nothing can prove, better than these great co-operative triumphs, that the days of competitive strife between compressed air and electric power have permanently passed.

DISCUSSION.

K. F. Stahl, Member—What kind of trap is best adapted to drain the water which condenses in air pipe lines? Can a trap similar to those stream traps in which a float opens and closes the discharge valve be used?

L. I. Wightman—I know of no special device for this purpose. In our experience we have sometimes installed steam traps, but I have never heard the results secured. It is a minor accessory of the plant and is something that the compressor people usually have nothing to do with. But I can see no reason why such a device should not work satisfactorily.

C. B. ALBREE, Member—There is another method of compressing air that is not used very extensively as yet, i. e. compressing by a stream of water running down a vertical pipe. The principle is very simple, as it simply carries the bubbles of air down with the water; and as the stream gets down to the bottom the hydraulic pressure compresses the air. They have a hood over the tank at the bottom of the pipe that catches the compressed air, while the water is allowed to escape.

S. B. ELY, Member—The point was brought up of combinations of air compressors and gas engines. If air under 20 to 25 pounds pressure is called compressed air, then today in Germany there are a number of large installations where gas engines drive the compressors. They are used for blowing engines in connection with blast furnaces and are in very large units. The gas engine cylinders are 800 to 1000 horse power, the blowing tubs being as large as 60 to 72 in. diameter, delivering something like 30,000 cubic feet of free air per minute. Such an installation can now be seen in this country at the Lackawanna Steel Company, Buffalo, N. Y. There is a very considerable saving effected in the fuel bill over the best compound steam blowing engines, only ½ to ⅓ the fuel being required to do the same work.

Moisture in air can be gotten rid of in a similar manner to the way dust is gotten out of blast furnace gas by centrifugal fans. The air is admitted to the fan, and, being thrown around very rapidly, the heavy particles of moisture are thrown by centrifugal force to the outer casing of the fan and drain down into a trough. This action, of course, presupposes that the moisture in the air is not in the form of vapor, for in that case, it being a gas and the air being made up of gases, the law of diffusion of gases would prevent separation, but if the air is chilled before going into the fan, by expansion or otherwise, chilled enough to create a mist, the finely divided particles of water in suspension can then be thrown out by centrifugal force.

The speed of a fan, however, is limited by the strength of the steel in its blades, so there is a practical limit to the centrifugal force that can be developed. It has been suggested, and I believe some experimental work has been done in using a spiral through which the air is forced. The spiral being stationary, the air can be put through with any required velocity, consequently any centrifugal force developed that may be desired.

C. B. Albree—The question of the dryness of air is a very important one to users of pneumatic tools. Mr. Gayley, of the U. S. Steel corporation, conceived the idea of freezing the air, thus precipitating the moisture and getting dry air for the blast furnaces.

S. B. Ely—In connection with freezing air for blast furnace work, the air passes through a room filled with pipes, which, I believe, have brine circulating through them, the brine being kept cool by large ice machines. The air is chilled on striking the cold pipes and moisture collects on them in the form of snow or frost. When the pipes are well covered, steam is let into an occasional pipe and that pipe thawed clear.

I have always been under the impression that the same result could be accomplished by the expansion of air with a properly designed set of cylinders. The difficulty would be to get the moisture out of the air after it was once precipitated in the form of mist, which could doubtless be accomplished by the centrifugal principle already referred to.

H. S. Hunter, Member—There is a device for drying air that is inexpensive but fairly satisfactory. It is located at a convenient point on the air line, between the receiver and where the first branch line is taken off. It consists of a receiver made from a section of pipe about four times the diameter of the main line, and several feet long, arranged in a vertical position. The inlet pipe is carried through the center of the top head and extends down to within six or eight inches of the bottom. There are two outlet connections, one on

each side of the inlet pipe in the top head, the combined areas of which equal the area of the main or inlet pipe. A valve or cock should be placed in the lower head for blowing out the moisture as it accumulates. This device brings the air in contact with more pipe surface during its passage to the tools. In a measure, it is an improvised trap for lowering the temperature of the air and collecting the moisture. In a great many cases it eliminates the moisture to the extent of preventing the pneumatic tools from freezing at the exhaust during cold weather.

C. B. Albree—Have you not found, in using air expansively, in motors for instance, that if you have dry air there is no trouble in working it down to very low pressures?

L. I. Wightman—In the Cleveland Stone Company's plant they use cold, dry air down to 3/8 and even 1/4 cut-off and have had no trouble.

A. A. Lane, Member—Do they do any reheating?

L. I. Wightman—They use reheating now. They ran several months on cold air before they got in the reheating plant. The reheaters they use are very simple affairs, with return coils of iron pipe in a brick setting with a little fire box at one end about two feet square. The total cost of reheating fuel in that plant, on machines aggregating about 850 horse power, was $1.00 a day. They experimented some with reheating in the Cleveland plant, running their initial temperature as high as 700° F., and found they still got good lubrication; but they have not maintained these high temperatures.

A. Stucki, Member—I understood Mr. Wightman to say that the gas engines so far have not been used for driving compressors. Is there any special reason for it?

L. I. Wightman—There has not been a demand for it. I believe the difficulties encountered thus far have been purely mechanical, and can be overcome as a fuller understanding of questions of design come with more experience.

H. C. Cronemeyer, Member—They have, at a gas well in Virginia, an air compressor of some 3000 horse power, driven by a gas engine and used for pumping natural gas to a great distance. When a Pittsburgh firm was considering the subject of gas engines for power purposes, among other engines which they looked at was this gas engine driven gas compressor, and it was claimed to be very effective.

A. Stucki—What composition of metal do you use in the valves and valve seats.

L. I. Wightman—Drop forged, oil-treated steel for the valves, which usually seat on the metal of cylinder heads or cylinders.

A. A. Lane—Is the speed regulated by throttling?

L. I. Wightman—Only in Meyer valve types; in large Corliss compressors there is a very slight change in cut-off. The governor shifts slightly but so little as to be hardly perceptible. Of course there is bound to be some change of cut-off to change the speed.

*COKE AND ORE BINS.

† E. W. PITTMAN.

Member.

Coke and ore bins, to which the discussion of this evening is limited, are used principally in connection with blast furnaces. So greatly do they facilitate the handling of the materials between the stock pile and the furnace skips that they have come to be regarded as an indispensible adjunct of a modern blast furnace plant. Whenever the conditions will permit, these bins are designed to receive deliveries of material direct from bottom or side dumping cars running on overhead tracks. This generally requires a trestle approach on a grade, and the room for this approach is not always available. In such a case, deliveries are made into the bins from the stock pile by means of grab buckets operated from conveyor bridges or derricks. The latter method of delivering materials to the bins from the stock pile should be available whether there is an overhead track or not, as during severe winter weather ore shipments are sometimes suspended, and the stock pile, accumulated during the summer, is the only source of supply.

The coke and ore are drawn from the bins, through gates and chutes, into cars or buckets for final transportation to furnace skips. These gates are located in the bottom of the bins and are operated either by hand levers or by some power driven mechanism.

Coke and ore bins are constructed in various types and the materials entering into their construction are wood, con-

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* Meeting of Structural Section, May 22, 1906.

† Lewis Building, Pittsburg.

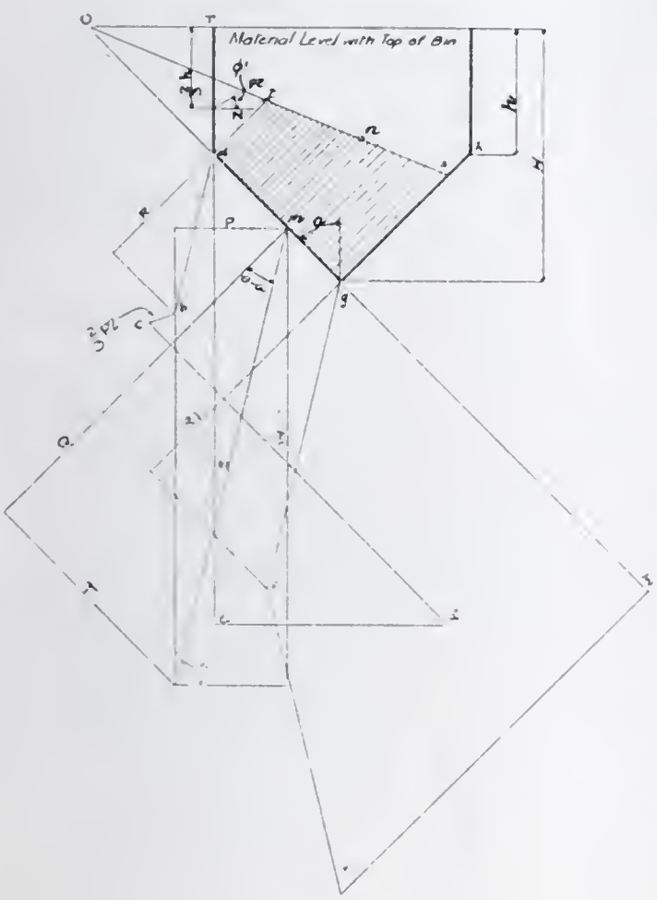
crete and steel. Wood is not as much used for this purpose as formerly, though it has not been entirely superseded by steel and concrete. Bins are sometimes constructed with steel frame lined on sides and bottom with wood. Due to the increasing cost of timber, however, and also to considerations of durability, the tendency at present is to use less wood and more steel and concrete in the construction of bins and allied structures around a blast furnace plant. Steel and concrete are often used in combination, the main members being of steel and the side and bottom lining of concrete. Sometimes this concrete is in the form of arches between adjacent beams and sometimes of reinforced flat slabs. More often, however, the lining is of steel plates. Plate lining is about as durable as concrete and, of course, much cheaper. It also affords better connections for the gates than does concrete.

Coke and ore bins may be classified under two general heads, namely, the box or prism shaped type and the parabolic suspension type. Bins with vertical sides are usually provided with hopper bottoms, so that all of the material may be drawn off through the gates at the bottoms of the hoppers.

After the size and type of bin has been determined, the next step is to obtain and arrange in convenient form all data necessary for the computation of the stresses in the various members of the structure. This consists essentially in determining the direction and intensity of pressure of the materials on the different parts of the bin. These pressures depend upon the nature of the material, and are functions of its weight and angle of repose and the coefficient of friction between the material and the bin walls. The pressures are most conveniently represented in the form of force polygons, and should be drawn in proper relationship to the cross section of the bin. After the polygon of external forces has been thus plotted, all necessary data is at hand to compute the stresses and bending moments in the various members of the bin, and the balance of the operations do not comprise any novel or difficult features.

The only difficult or tedious part of the work consists in

determining and graphically representing the external forces. The principles involved are the same as those deduced by Prof. William Cain. These have recently been still further elaborated and placed in more convenient form for the use of the bin designer by Mr. R. W. Dull, whose excellent article on this subject appeared in Engineering News of July 21, 1904. The formulas given in Fig. 1 are taken from this article. Those interested in the derivation of these formulas are re-



Notation

w = Weight of material per Cu Ft.
ϕ = Angle of repose of material measured from a horizontal plane.
ϕ_1 = Angle of friction bet. mat. & bin wall.
a = Angle bet. bin bott. and a vertical plane
H = Total height of bin
h = Height of bin from top of hopper.
P_2 = Total thrust against bin wall for a section 1 thick.
N = Normal component of P_2.
E = Total pressure against hopper bottom 1 to sec
P = Horizontal component of E
W = Vertical " " "
Q = Component of E normal to hopper bottom
T = " " parallel " " "
R = Reaction at a due to Q
R_1 = " " Q " " "
θ = Angle of E measured from a hor. plane

Then $P_2 = \left(\frac{\cos\phi}{\sqrt{\frac{\sin(\theta-\phi_1)\sin\theta}{\cos\phi_1}}-1}\right)^2 \frac{wh^2}{2\cos\phi_1}$

$N = P_2 \cos\phi_1$
$P = \tan^2(45^\circ - \frac{\phi}{2})\frac{w}{2}(H^2-h^2)$.
$W = \frac{w \tan a}{2}(H^2-h^2) - P_2 \sin\phi_1$
$E = \sqrt{P_2 + W^2}$
$\tan\theta = \frac{W}{P}$
$Q = E\cos(\theta - a)$
$T = E\sin(\theta - a)$,

Produce ag to O - at middle point of ag erect the normal line mn, making it proportional to $\frac{Q}{(H-h)\sec a}$.
Through n draw ons - Draw at o gs normal to ag.
Then the Trapezoid, $atsg$, represents the loading on ag
Then $R = \frac{at \cdot ag}{5} + \frac{gs \cdot ag}{6}$ and $R_1 = \frac{at \cdot ag}{6} + \frac{gs \cdot ag}{3}$
Lay off R & R_1 and their components ab & gf parallel to E.
Then draw force polygon for g as follows, gf-fi-ih-hg
Then draw force polygon for a, as follows, ab-bc-c ($\frac{1}{2}P_2$)-cd ($-gh$)-de-ea - de represents the stress in the strut ak, and ea the vertical reaction at a for a section one foot thick.

FIG. 1.

ferred to Prof. Cain's work on Retaining Walls. For any given material, of course, the weight per cubic foot and the trigonometrical functions of the angle of repose, or natural slope, and of the angle of friction with the bin walls, are constants. These constants have been worked out by Mr. Dull for several different kinds of materials in steel plate bins, and tabulated in the form of coefficients of the variable height "h," thus rendering the formulas easy of application where these partic-

ular materials are concerned. But even without the table of constants, the equations can be quickly solved with the aid of a slide rule. The force polygon is a check on some of the computations, and it is apt to make apparent any large errors in the solution of the equations.

Bins of the type illustrated by Fig. 1 are very much more expensive than the Berquist, or parabolic, suspension bin, in that they require twice as much steel work. In a parabolic bin there are no bending stresses in the plates, therefore no stiffeners are required. Every part of the plate is in simple tension. In large bins of the Berquist type no shaping of the plates in the shop is necessary. The plates are sent to the field flat, and when erected assume the parabolic form under the elastic deflection due to their own weight.

An interesting example of parabolic bin construction is to be seen at Carrie Furnaces, Rankin. The bins are suspended from heavy longitudinal girders with two web plates which form an inverted triangle, the top cover plate being the base. The web plates are equally inclined to the vertical, one of them being tangent to the parabola and projecting below the bottom flange to afford a connection for the suspended bin. The longitudinal girders are supported at intervals of 12 or 15 feet by heavy plate and angle columns. At each pair of columns there is either a partition or a deep transverse strut to resist the horizontal component of the pull from the bin plates. The gates in the bottoms of these bins are spaced about 6 or 7 feet apart, and are arranged to deliver alternately to the right and left. Each gate is operated by an independent steam cylinder and valve. Deliveries are made through chutes into larries suspended from longitudinal I beam tracks below the bins. These tracks are supported at each bent by the transverse frames between columns. The larries and the electric locomotives which propel them run on the bottom flanges of the I beam. Deliveries are made from the larries into the furnace skips.

Fig. 2 shows a general cross section of coke and stone bins recently erected for the Lackawanna Steel Company at Buffalo.

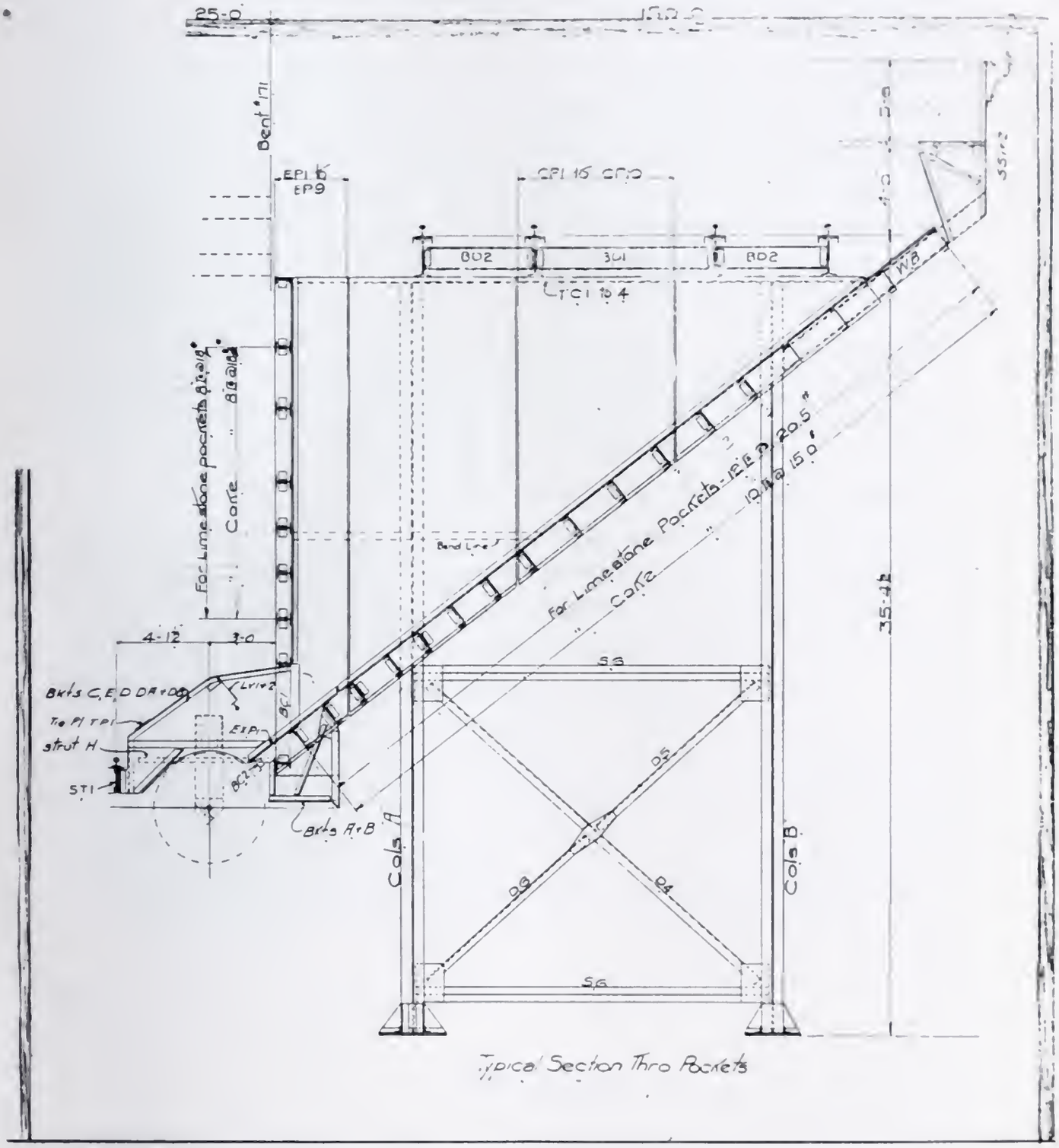

25-0
Bent #171
EP1 to EP9
CP1 to CP10
BD2
BD1
BD2
TC1 to 4
W8
For Limestone pockets 8 @ 18"
Coke 8 @ 18"
For Limestone Pockets-12 @ 20.5"
Coke 10 @ 15.0"
Bend Line
35-4½
4-12
3-0
Bkts C, E, D DA+DB
Tie Pl TP1
strut H
ST1
EXP1
BC1
BC2
Bkts A+B
S6
D5
D3
D4
Cols A
Cols B
Typical Section Thro Pockets

FIG. 2.

They are divided into panels of 12 ft. 6 in. center to center of columns, with a double partition at every panel point, leaving the clear length of each pocket about 11 ft. 6 in. The general features of the coke and stone bins are the same, though of course lighter sections were used for the coke bins. Diaphragms are placed between the partitions to prevent the plates from buckling under the action of the normal thrust. These diaphragms also perform the functions of a beam in transmitting the normal thrust to the floor at the bottom and to the transverse channel at the top when one pocket is filled and the adjacent one is empty. The bins are lined throughout with 3/8 in. plates. All rivets in the floor are countersunk.

Deliveries into these bins are made direct from bottom dumping cars which run on the tracks above, and also from buckets operated from a conveyor bridge.

The gates at the bottoms of the bins are of special construction. They are cylindrical and are revolved by a system of shafting and gears. There is an opening in the side of the drum, and when the drum is revolved this opening comes opposite the opening in the bottom of the bin and the drum is filled. When the drum is further revolved and the opening turned down, its load of material is dumped into a larry for transportation to furnace skip. At the same time communication between the bin and drum is shut off. The most notable feature of these gates is that they measure the material delivered to the larries. The larries are suspended from the tracks shown in cross section on either side of the gates.

DISCUSSION.

R. H. Dempsey, Member—The construction we have been using for bins has been a steel frame with cribbed body lined with steel plate. It makes an economical bin for the storage of coal and, with the crib construction, is practically fire proof, the cribbing being very slow burning construction. Our bins

are of the straight bottom type with hopper and undercut gate. They are not exactly similar to the ones shown by Mr. Pittman, as ours are mostly built for coaling locomotives and the gates are different.

The most practical gate today is the undercut gate, being a pivoted gate swinging up in an arc. It is mechanically perfect because it is working against free coal all the time on the rise, and on the return it is simply working in an arc and has nothing to overcome except friction. I suppose the argument in favor of using the cylindrical gate is that it measures the material delivered.

A. Stucki, Member—With a gate of the drum type I would expect trouble from freezing, as the gate will continuously rub against the bin and its contents.

E. W. Pittman—The drum is not tangent to the circular part of the bin, though it comes close to it, so I do not see what would make that bond except material that might be jammed between the drum and the chute, and that would be sheared by the gate. The gates are operated by steam cylinders which are powerful enough to do that.

K. A. Muellenhoff, Member—Mr. Pittman says that the parabolic bin has no bending moment. That is not strictly true because the parabola is a funicular curve for an equally distributed load. The funicular curve for a parabolic load is another curve, perhaps a parabola of the fourth degree.

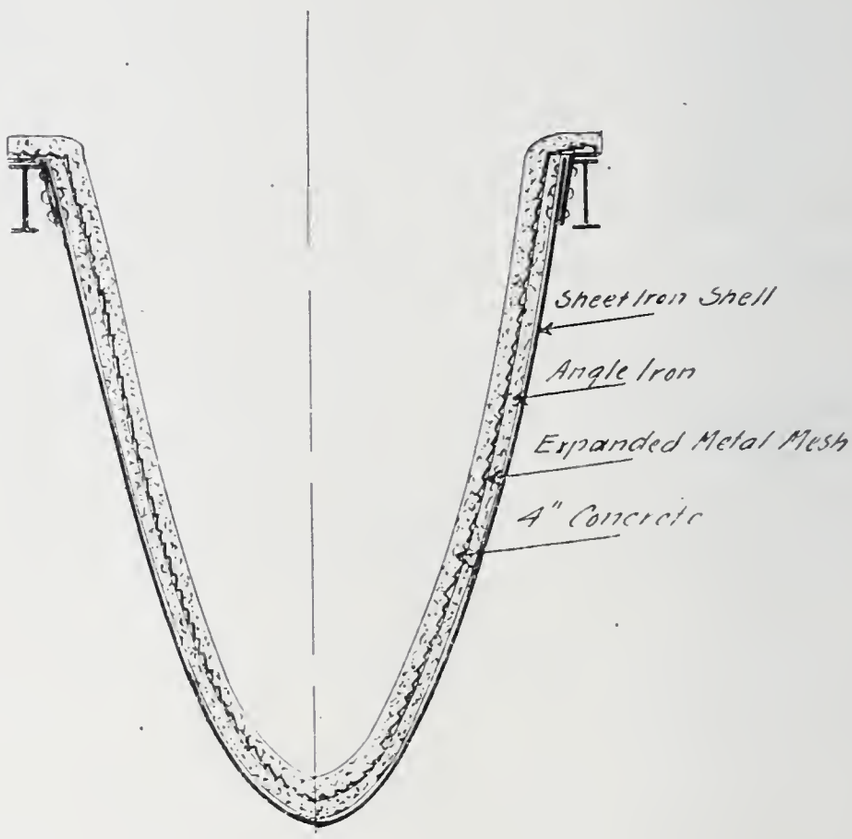
E. W. Pittman—That is true. I should not have said there were no bending moments, because there are, but not enough to be serious.

J. L. Klindworth, Member—What are the relative weights of square bins and parabolic bins per ton of contents?

E. W. Pittman—I have never analyzed an estimate on the basis of the weight of the material in the bin. A square bin, however, weighs about twice as much as a parabolic bin.

R. H. Dempsey—In comparing the costs of bins, I have found that the steel frame with cribbed body lined with steel costs somewhat less than the steel frame with concrete body, and that both cost less than one entirely of steel. With the entire bin built of wood the cost is just about half that of the steel bin. As to the cost per ton of coal contents, it varies so with the size of the bin and the arrangement of the supports that the information would be of no value.

D. H. Littell, Member—I have lined parabolic bins with concrete, bracing the sides with angle irons enough to take care of any bending moment. We then placed expanded metal outside the angle irons and covered the outer surface of the bin with concrete to a depth of about four inches. Those bins were used for coal and cinders. The object of lining them with



Sketch of Concrete lined Parabolic Coal Bin.

Fig. 3.

concrete is to keep the sulphur away from the iron, so that the life is practically indefinite. When the concrete wears out, as it will in time, you can re-line it and it is as good as new. We have also lined square bins, filling in the corners so that the contents can all run out.

As to the relative costs of reinforced concrete construction and steel frame lined with concrete, in any kind of building, it is "horse and horse." There was a time when it was supposed that reinforced concrete could be erected for less than wood construction, but a great many have paid the price to learn differently.

A. Stucki—Some years ago, in the East, a very large bin failed on account of the ties giving way. The posts, braces and other details were apparently sufficiently strong, which was possibly due to the fact that it is very easy to get those stresses. With the side pressure there seems to exist some doubt. I know of several different methods followed by different engineers.

In figuring the side pressure, I bisect the angle formed by the vertical wall and the angle of repose, and use the triangle nearest the wall as a basis for the maximum pressure, which is obtained by multiplying the enclosed weight by the vertical side divided by the horizontal side. The point of application of this side pressure is ⅓ the height from the bottom. The heaping of a bin very materially affects the strains, especially the side pressure, therefore it should always be considered the maximum load.

Willis Whited—What you get when you calculate these stresses mathematically is a maximum. You will very seldom get anything like that experimentally, as the material packs together. If the bin is very high the pressure on the bottom is often very much less than the weight of the material contained. After reaching a certain limit the friction due to the pressure on the sides will almost hold up the material in the bin.

Speaking of parabolic curves, if we calculate the pressures theoretically they will vary quite widely according to whether the bin is full up to one point or to another, and also whether it has been filled and drained out at the bottom so that it slopes down toward the center. At the same time it is approximately correct under full load. With grain the conditions correspond much more closely to theoretical conclusions.

K. A. Muellenhoff—Even for grain experiments have shown that as soon as the height of the bin is about three times its diameter the pressure does not increase very much.

Some time ago I had occasion to design a coal bin where we had some special conditions. It was for a boiler plant, the boilers being in two rows about 30 feet apart, between which I had to erect a coal bin with a track underneath. We wanted to have the coal pretty close to the boilers so we proposed chutes running from the bottom of the bin to about two feet from the floor. Then the coal will run down until the angle of repose is reached by the coal pile at the bottom of the chute.

Lest there should be any blocking of the chute we proposed to build, on the lower part of the bin, near the entrance to the chute, a series of louvres which could be worked with a crowbar by the fireman and thus free the chute.

R. A. Cummings, Member—What is the angle of repose of coal and ore?

R. H. Dempsey—40° for coal.

K. A. Muellenhoff—It depends on the size of the coal. I have measured fine coal 27° to 28°.

A. Stucki—Sometimes it runs very much higher, especially when moist. We have often sloped the sheets 45° and of late even 60°, to make sure of them clearing. Of course with slopes of 60° at both the end and the side you don't get 60° slope in the valley.

Willis Whited, Member—When ore dust and dust from

furnaces gets on iron it is apt to corrode it, for there seems to be some kind of free acid in the dust. Do you have that trouble in ore bins made of steel?

RALPH CROOKER, JR., Member—I never noticed that ore bins rusted out faster than steel bins used for other purposes. If dust from the furnace should alight on iron it would be likely to rust it because of the sulfuric acid formed when the rain falls upon it.

*FILTRATION.

With Especial Reference to the South Pittsburgh Water Co.'s Plant.

† J. N. CHESTER.

Member.

The South Pittsburgh Water Co. was first known as the St. Clair Water Co., and was organized in 1894-5. It was the outgrowth of dissatisfaction of some South Siders with the rates of the Monongahela Water Co., and a Mr. Grimes, who was also president of the Knoxville Land & Improvement Co., in a mass meeting, called to protest against the rates charged by the Monongahela Water Co., made a proposition that they organize an opposition company. The movement seemed to be popular and Mr. Grimes was made president and Jacob Schineller was employed as engineer. The pumping station was located at the junction of Becks Run and the Monongahela River. The territory that they contemplated supplying at that time was practically that territory being furnished by the Monongahela Water Co., but they went further up the river and set their force mains well back of the more thickly populated territory supplied by the Monongahela.

The principal pumping plant took its supply from a filter gallery in the river, which is still in existence and yields the amount it was designed to supply, viz., 3,000,000 gallons daily. The station originally consisted of a battery of four Heine boilers and two vertical Worthington pumps, one a high duty compound condensing and the other a low duty compound condensing, the general specification for which was that with 125

* Meeting of Society May 15, 1906.

† 1200 Bank for Savings, Pittsburgh, Pa.

pounds steam pressure each pump would deliver daily 3,000,000 gallons of water against 270 pounds water pressure. These pumps are still in service.

The force main, which was a 20 inch steel riveted pipe to about half way up the hill, the remainder being cast iron, lay along Becks Run until the first branch takes off to the west, which branch it followed to its termination in two tanks which served as a reservoir at the highest point in the borough of Mt. Oliver. These tanks are 66 feet diameter and 30 feet high and are still in use, but will soon be out of commission. From these tanks they laid an 18 inch force main to within the limits of the borough of Crafton, where a 2,000,000 gallon reservoir, a fine stone structure, was built as a storage basin to supply the Chartiers Valley. From this they built up and down the Valley to McKees Rocks, Sheridan, Ingram, Chartiers Township, Crafton, Carnegie, and Bridgeville.

The existence of two water companies in the same field resulted in just what it always does, cutting of rates and loss of money by both companies. Consequently the finances of both got in bad shape and they finally agreed to a division of the territory. That division is still respected; the Monongahela Co. supplies that territory inside of the City of Pittsburgh and McKees Rocks. The territory supplied by the South Pittsburgh Water Co. comprises twenty townships and boroughs, occupying a territory of 110 square miles and having an average population of about 1,000 per mile. The area embraced extends from Lincoln Place and Homestead on to the east to Whitehall and Bruce Station on the south-east, to Bridgeville on the south-west, and the extreme west bordering on McKees Rocks.

A pressure of 270 pounds for pumping engines to work against is pretty severe, especially after the capacity of the gallery built by Mr. Schinneller was exceeded, and it became necessary to draw raw water from the Monongahela River, which at times is full of grit and oftentimes of cinders. This severe service, and the consequent running down of the machinery, together with an unhappy state of affairs in the manage-

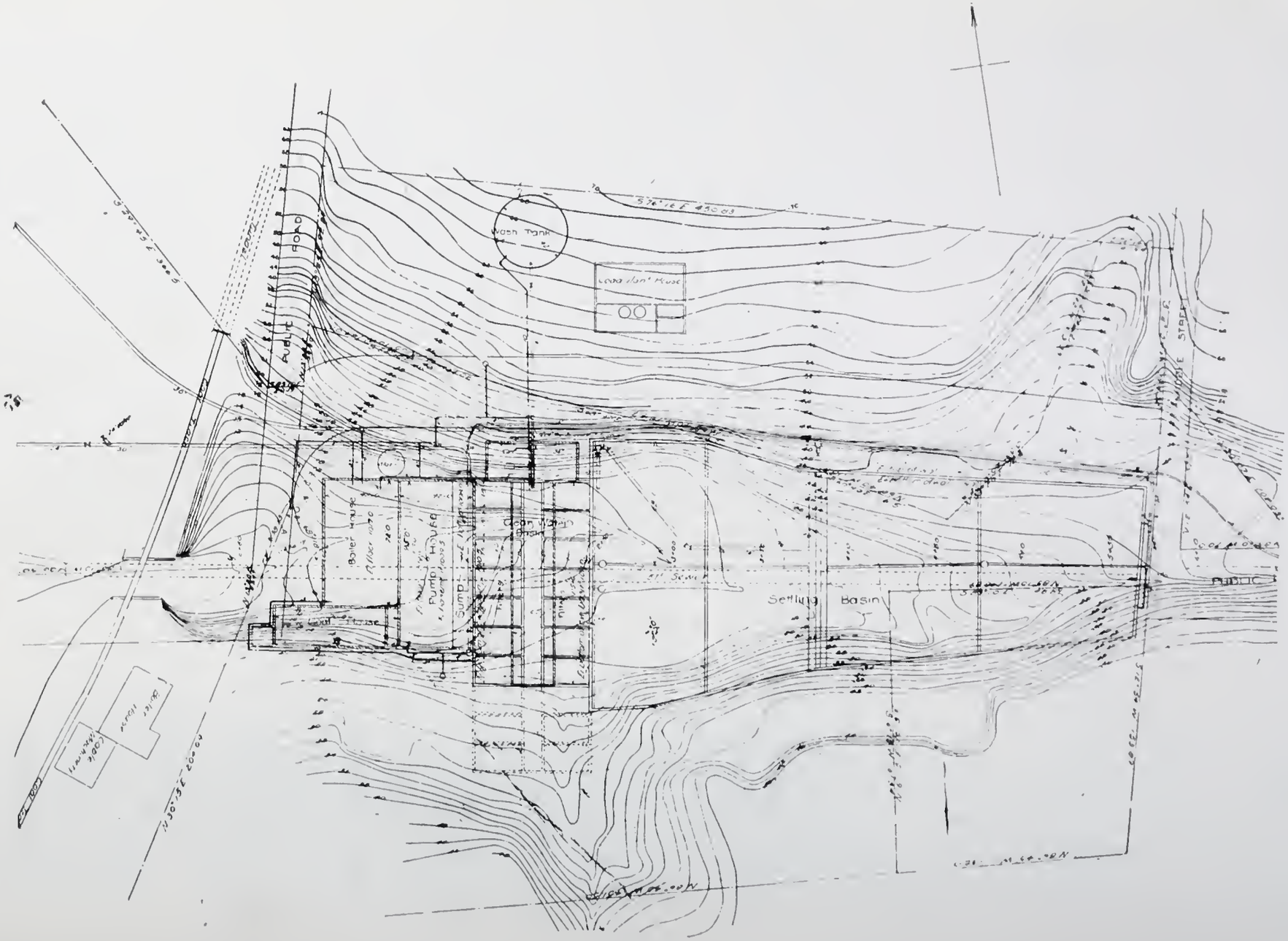

Wash Tank
Settling Basin
Boiler House
Pump House
Sump
PUBLIC ROAD
PUBLIC

FIG. 1.

ment of the water company, brought things to a crisis. As many of you remember, a few years ago the newspapers frequently noted that the residents of the South Side and the Hill district were without water for two or three days and sometimes weeks. Such a state of affairs, of course, could not continue, and the result was they sought a purchaser, which was found in the American Water Works & Guarantee Co., and not quite two years ago this company took hold. We immediately began a study and investigation of conditions with a view to the betterment of the service, intending to supply not only plenty of water at all times, but good water at all times.

First, we decided that we had to have more pressure at some points for an adequate supply than that carried by 270 pounds. Prior to the acquisition of this plant by the American Water Works & Guarantee Co., in order to supply some of the higher areas, a pumping station was built adjacent to the Mt. Oliver tanks, and water from these tanks was pumped into two tanks at Whitehall 50 feet higher at their base than the tanks on Mt. Oliver. Also, when the Beechwood Co. opened up their addition in Baldwin Township and West Liberty, a pumping station was built adjacent to the force line and water delivered to a tank on the highest point of the Beechwood subdivision. The inhabitants of the Chartiers Valley insisted on building on higher points than the Crafton reservoir and it became necessary to build a tank up above Sheridan. The question arose of the continuance of these stations and building others versus the increasing of the pressure over the entire area sufficient to supply all points. The latter plan required 120 feet additional to the height of Mt. Oliver tanks and something like 60 pounds additional pressure to the 270 pounds for which the pumps were designed. The extreme pressure of 270 pounds had caused very high repair bills, and the frequent breakdowns were the reasons for the high places being without water so frequently. It was not deemed possible to put this extra head on the pumps. Our main aim was to utilize to the utmost what the company already possessed, and to equip

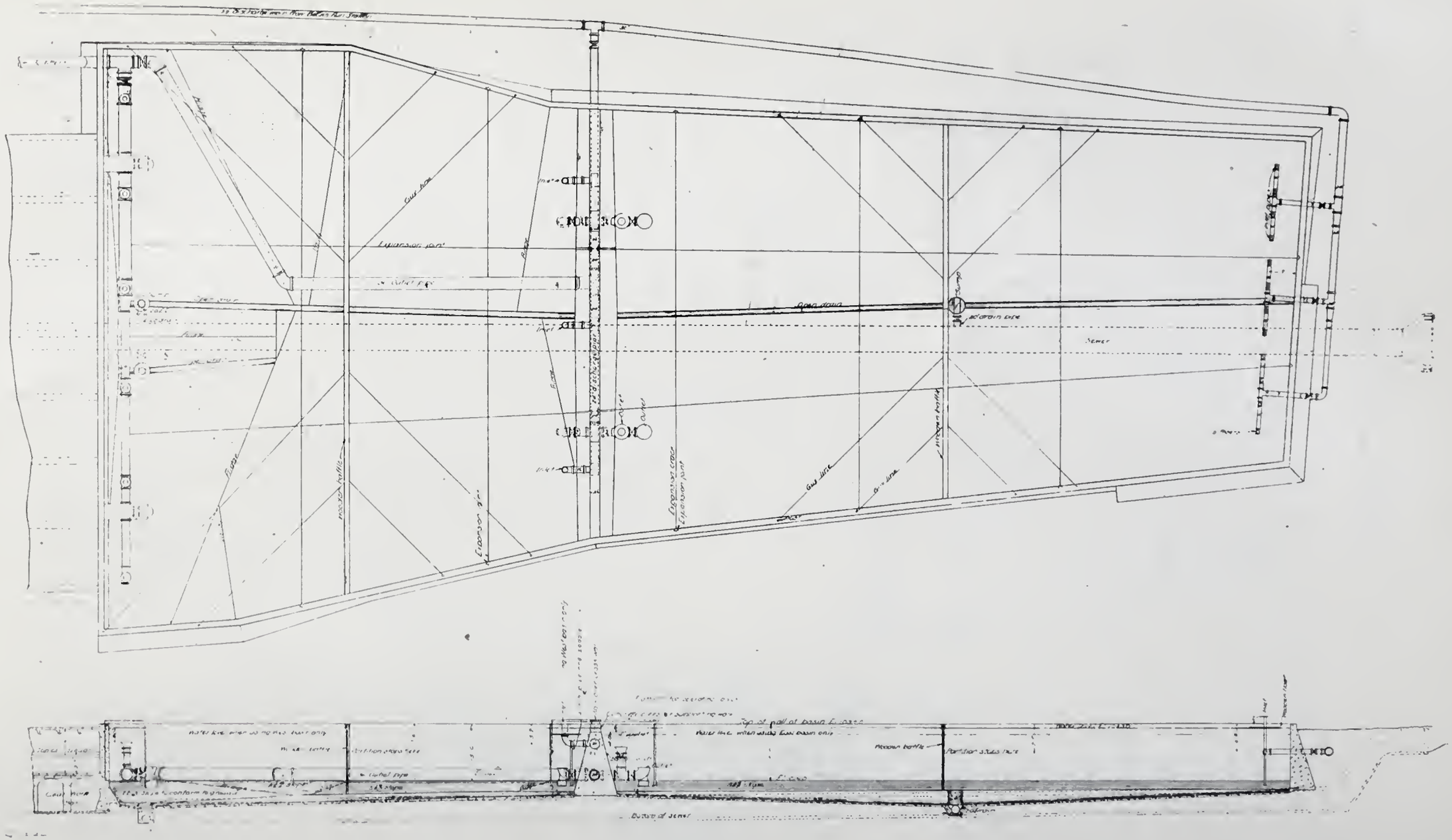


FIG. 2.

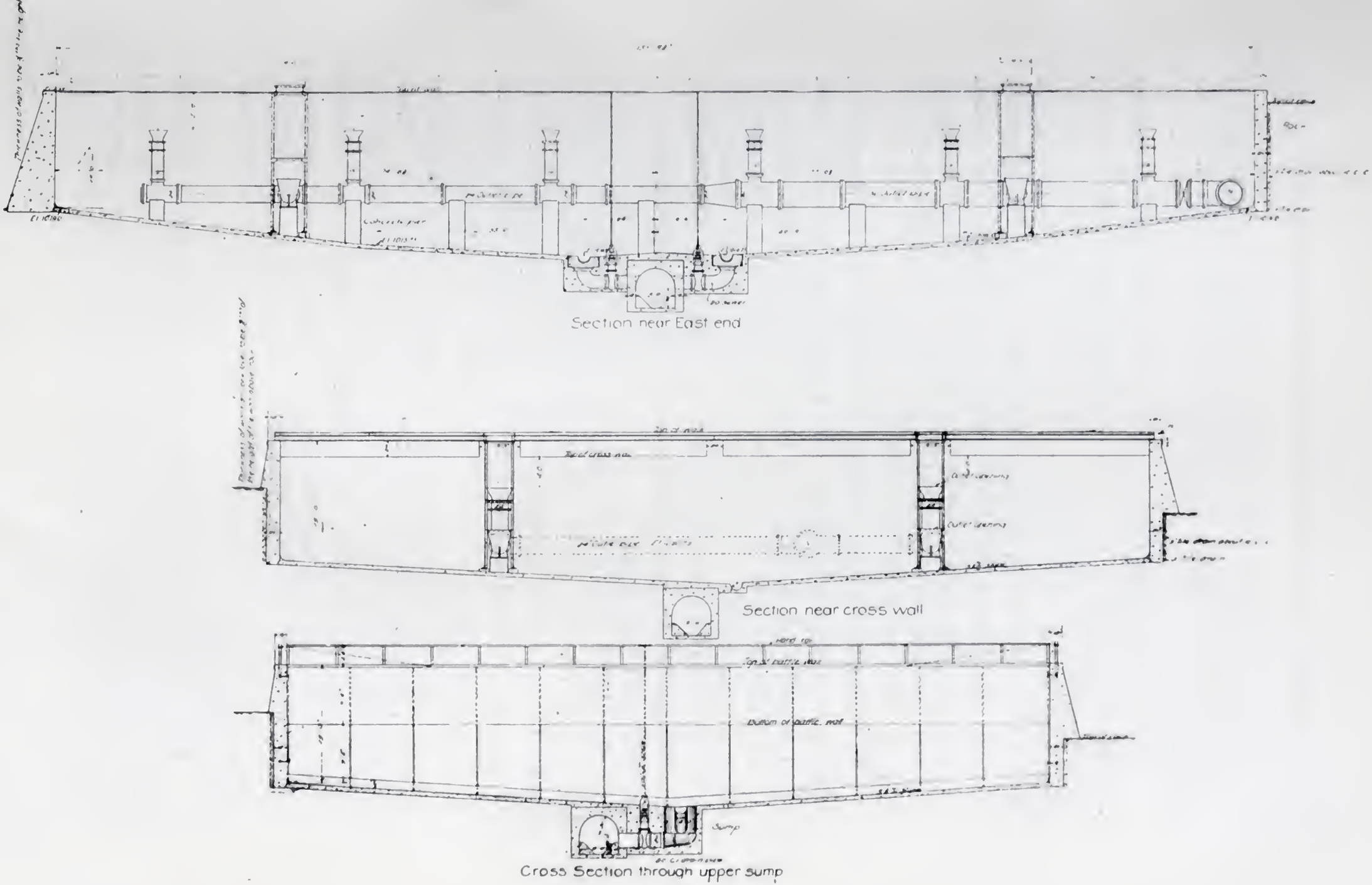

Section near East end
Section near cross wall
Sump
Cross Section through upper sump

FIG. 3.

the plant to provide good service by the least additions it was possible to make. To that end we made four different estimates.

One was on pumping low service from the present pumping station to just over the Pan Handle tracks and building a filter station at that point. That prevented the use of the pumping machinery, for in addition to the two Worthington pumps they had put in a 6,000,000 gallon Allis triple expansion vertical pump and a Heisler 3,000,000 gallon pump. That plan was handicapped by charging against it the old machinery, or at least the necessity of building entire new water ends for that old machinery, which ran up the cost.

We then made an estimate on the next location where a filter plant might be placed, which was along the force main when it takes off from Becks Run. To these plans could be credited a great deal of pipe line, but we had to charge against them the practical abandonment of the present machinery. Besides, there is not a great deal of horizontal real estate in this vicinity where you could locate even so small a thing as a mechanical filter plant.

The third location considered was only about 150 feet above the river. As the pumps were not strong enough to stand the pressure at which they were working, that also meant the practical abandonment of the water ends, and the reduction of capacity by the introduction of new ends.

The fourth location, or the one finally chosen, practically divided the total head and is located at the point where a small stream enters Becks Run from the east side, or at the foot of Agnew Avenue. It was a very narrow valley but it seemed especially adapted to the building of about the sized plant we intended. When the four locations were compared the fourth won out, altho we had to charge against it a force main some three miles long.

The selection was a commercial one, as every such decision should be; the utility features could have been worked out in either location. Having decided on the location and procured the real estate, which we had to do by getting the Pitts-

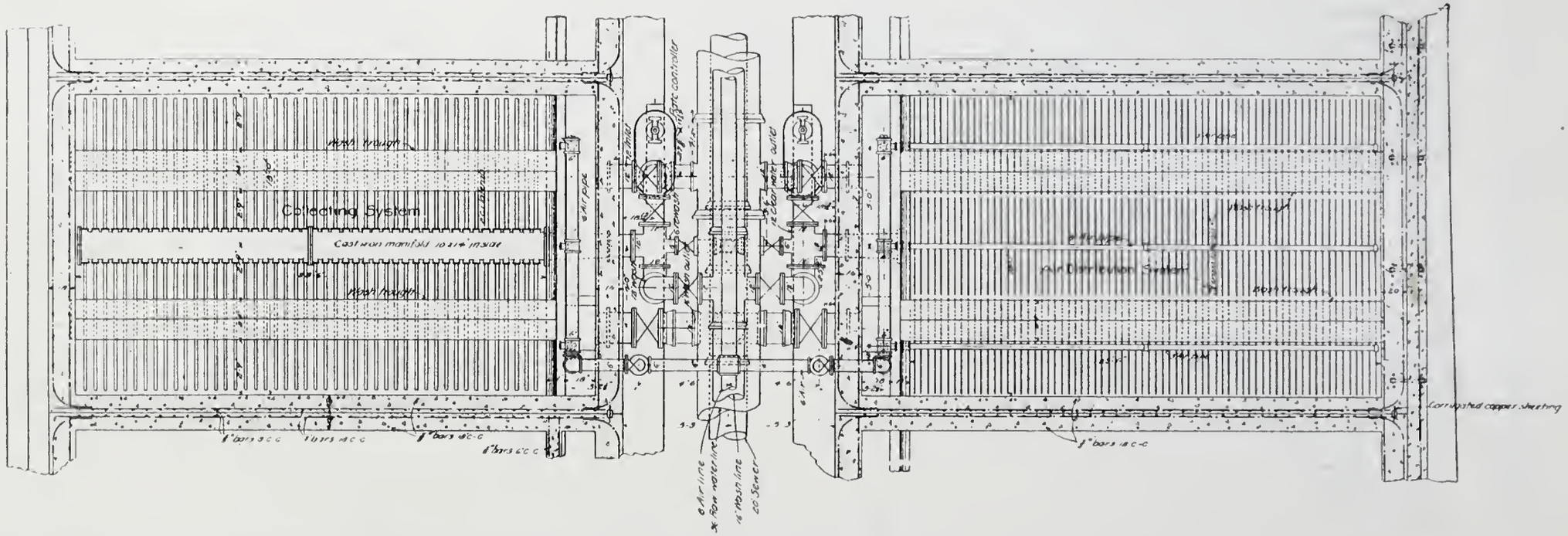
burgh Coal Co., and some homesteaders off some of the surface, on May 1, 1905, we began the excavation, and but a few days before that had begun the plans, altho we had pretty well decided what the nature of the construction would be.

Of course, in designing, we took advantage of the contour of the ground. The settling basins were created by cutting down the side hill. There was considerable excavation in the upper basin; some points in the lower basin there was practically no excavation. We had probably an average depth of earth and shale along these points of eight or nine feet from the surface, but then we had rock or coal, and in order to create the sides of our basin we gave the rock or coal a slight concrete veneer. When we reached a stratum that would not retain itself we offset and put in a retaining wall, so that the heavier part of the concrete work that might have existed in such a design was done away with by the amount of solid strata in the lower part.

The features above described are illustrated in Fig. 1, which shows the contours of the location as it originally was with the improvements laid out over same, and from this can be noted the sewer under all, the location of the settling basins, the dividing and baffle walls, the filters with the proposed extensions thereto, the pumping machinery room and the clear water sump, the boiler and coal room. Also across the relocated road is shown the coagulant house and wash tank.

At the lower end of these grounds and across the street is shown the cable station of the Becks Run mine from which we are to obtain our coal supply over a spur switch that will turn in back of their power station to the southward and terminating at the other end at the elevator at the west end of our coal house.

The settling basins have been built so that we can deliver into the upper basin and also take water from it adjacent to the dividing wall, carrying it across the lower basin, thus enabling us to clean the lower one without interfering with the operation of the plant. We can also deliver through the divid-



Sectional Plan

FIG. 4.

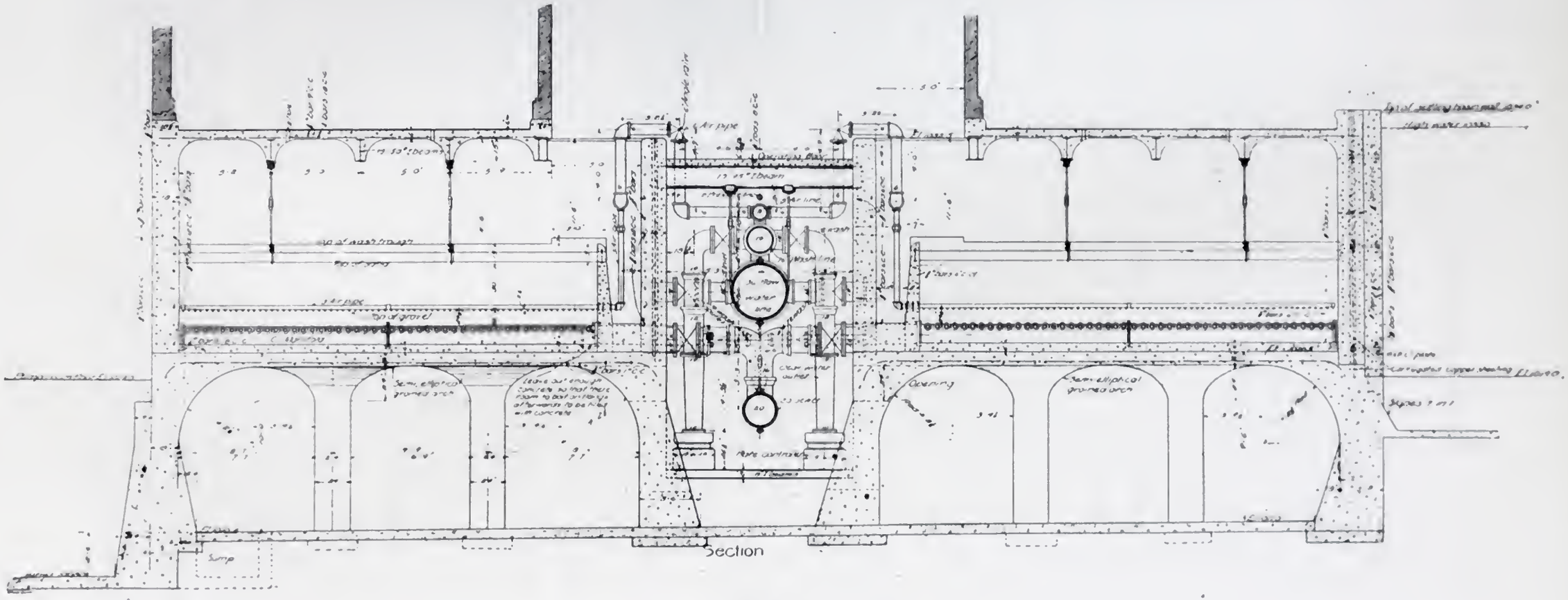


FIG. 5.

ing wall into the lower basin while we are cleaning the upper one. So we have complete control of our sedimentation basins for cleaning, repairing or otherwise.

The above features are illustrated by Figs. 2 and 3, Fig. 2 being the plan of the basin showing the supply main from the Becks Run station terminating in the distributing pipes or aeraters at the upper end. This plate also shows a longitudinal cross section in these basins from which the feature of the sloping bottom and the conduits for quick and ready cleaning will be noted.

The section near east end on Fig. 3 shows the drawing off facilities for the settled water. Section near cross wall shows the alternate facilities for obtaining settled water during the cleaning of either basin. Cross section through upper sump shows baffle or deflecting wall and also facilities for draining and cleaning the upper basin. The two last named sections also bring out the veneering of the coal and rock and the offsetting or widening further up into retaining walls.

The present demands on the plant averages 8,000,000 gallons daily. We are finishing 14 of the filters, which have a capacity of 1,000,000 gallons each, but having 10,000,000 gallons pumping capacity, we have built somewhat ahead, though in this fast growing territory not very much.

The filters are of the mechanical type, built of reinforced concrete, and beneath them is a clear water basin, the filters resting on the vaulted roof of the basin. In these filters there is 8 inches of gravel over the strainers and on top of that 30 inches of sand. Both the gravel and the sand came from the sea shore, the sand being a good grade of Jersey sea sand such as is ordinarily used in mechanical filters. The gravel is well washed, of uniform size and of specific gravity in excess of the sand used above it. It is smooth, round and heavy, with little tendency to be disturbed by the action of the washwater—being heavier than the sand it will settle below the sand when being washed. Air is used for stirring or agitating the beds when washing. The air pipes are placed above the gravel so that it will not disturb the location of the gravel.

A pair of these filters are shown in plan in Fig. 4, from which the concrete steel construction may be noted; the two overflow or wash troughs in each unit, and in the unit to the left may be seen the clear water collecting and wash water distributing system. In the unit to the right the air distributing system only is shown, and in connection with Fig. 6, the raw water inlet, the clear water outlet terminating in the controllers, the wash water inlet and the sewer or wash outlet and also the drain are indicated. Fig. 6 also shows the hydraulic valve control, the lost head gauge, the stand for regulating the controller, the air valve and the drain valve.

The four valves controlled hydraulically are the raw water inlet, the clear water outlet, the wash inlet and the sewer or wash outlet.

Fig. 5 shows a section through the two units in plan in Fig. 4. This section also shows the vaulted clear water basin beneath as well as a portion of the pump room to the right with one wall for same located on top of the end wall of the filters, a portion of the operating room of the filters supported on eye beams, the roof of the filters, a concrete steel veneer wall on the raw water basin side and the outlet roofing of the filters. This drawing taken also in connection with Figs. 4 and 6 further illustrates the piping of these filters.

Adjacent to the filter building, letting the filters form a part of the walls, is the pump room. The sump, or suction well, is about 18 inches lower than the clear water basin. The pumps are of the low duty horizontal triple expansion, or as I prefer to call them, three cylinder compound type, but there are more refinements for the production of economy in these pumps than in any of this type that have been previously built. They were built by R. D. Wood & Co. of Philadelphia, after the pattern designed and first built by Henry R. Worthington, who enjoyed a monopoly of them for some time until a few ingenious designers learned how to get around the patents. The refinements I refer to are provisions for the utilization of super-heat, the intervention of re-heaters between both low and intermediate pressure cylinders and between

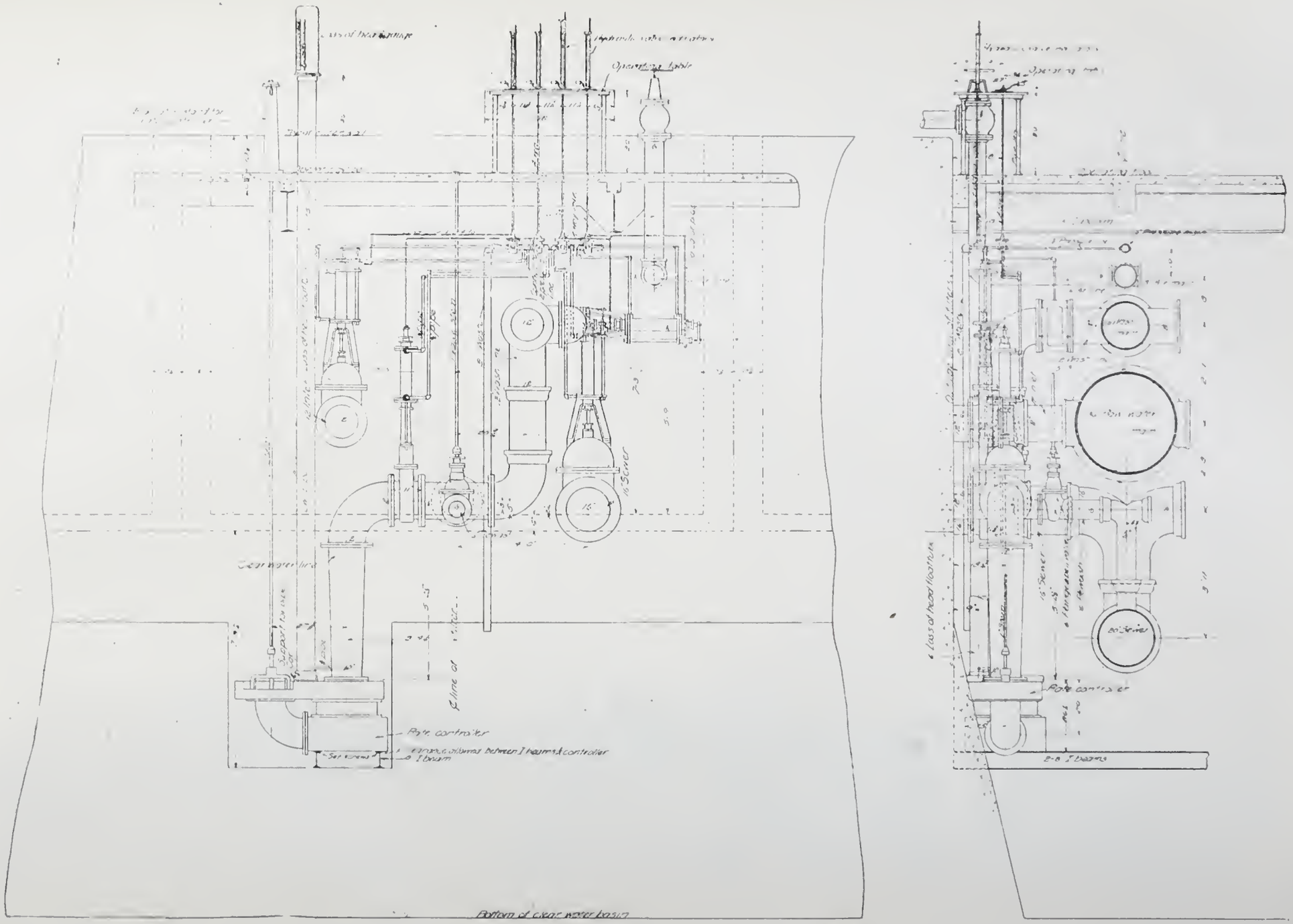

Operating table
Clear water line
Rate controller
Bottom of clear water basin
Loss of head floatbox
Rate controller
2-8 I beams

FIG. 6.

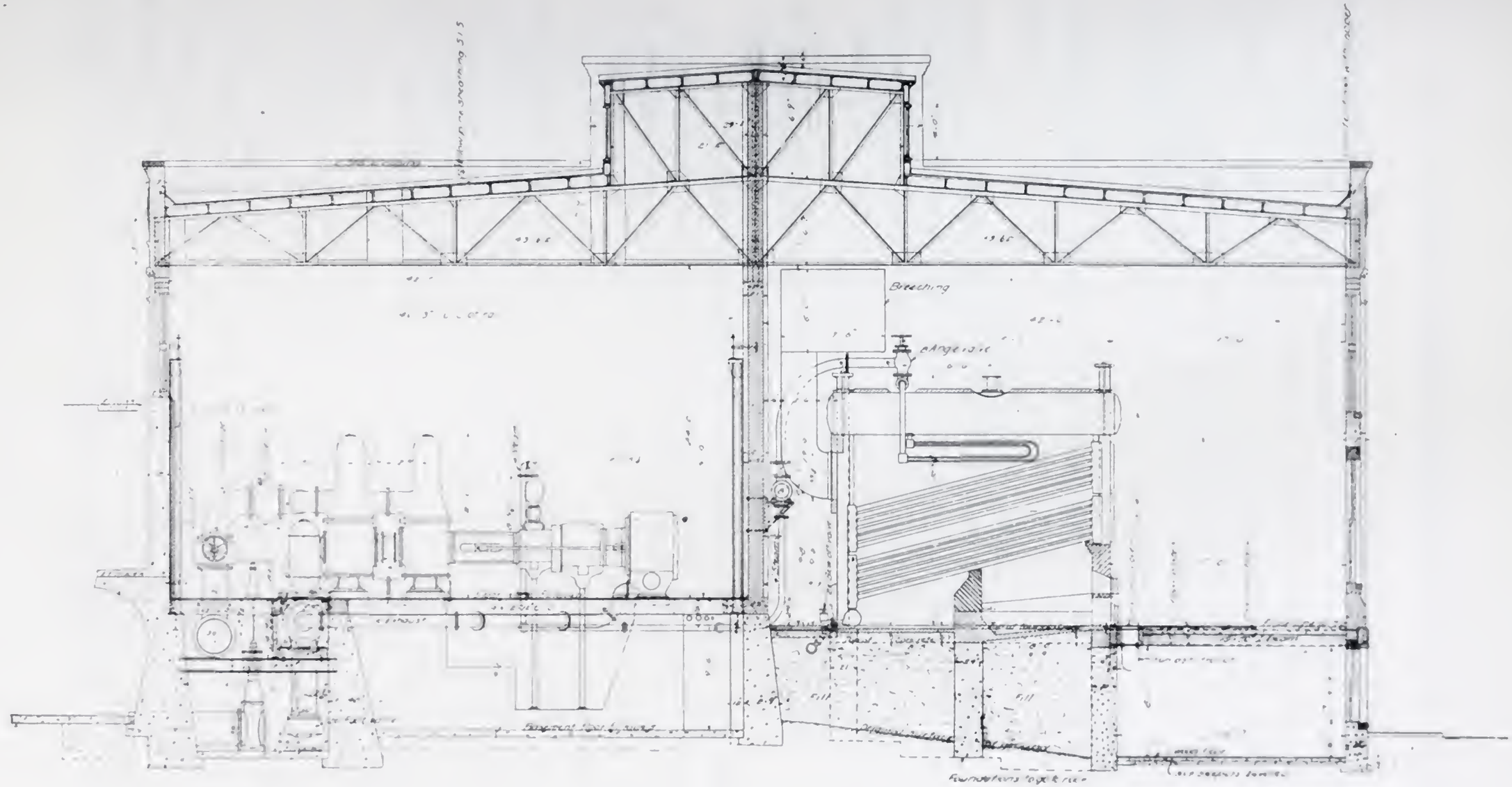


Fig. 7.

intermediate and high pressure cylinders and the jacketing of the low pressure cylinder with the exhaust from the intermediate cylinder, keeping excessive heat out of the exhaust and not make the condenser do more work than necessary.

The displacement chambers of the pumps are cast of steel as they are to work under 185 pounds. The discharge main is riveted steel and the check valves are steel tested to 500 pounds pressure.

The boilers, three in number, are the Babcock-Wilcox type with superheaters. The stack is of Custodis construction, 175 feet high, 78 inches inside diameter.

Fig. 7 shows a cross section through the pump and boiler room. This building was planned for five units of each, pumps to be of five million capacity against a total head of 185 pounds. the boilers being 300 horse power each. But three boilers and pumps are at present being installed.

The pump room is provided with a ten ton traveling crane. It will be noted that the pumps take their suction through a very short pipe in which the condenser is located.

Beneath the forward end of the boiler room will be seen the space utilized as a shop. This space also contains the firemen's toilet and the compression tank for the coal hoist elevator.

A feature of the boiler house is that we had to build up quite a way for our foundations, so we made and fitted up a workshop under the boiler house as well as a storehouse for pipe and fittings. It also contains the ash chute which runs along in front of the boiler house. The ashes fall into a drop and water washes them down the stream.

The coal house is rather a different construction from what you generally see, but we think it well suited to the conditions. Fig. 8 shows the coal house, the principal feature of which is the elevation of the coal in the original mine cars a vertical distance of twenty feet by a hydraulic elecator. At this elevation turn tables are provided for diverting the car to either side of the upper floor of the coal building where lever dumps are provided as illustrated. The lower

part of this coal room is floored with paving brick. It will store approximately 200 tons.

There existed, near the site of the station and above the level of what was the top of our settling basin walls and the top of the filters, a stone quarry, from which we were able to quarry enough stone to make all the concrete required in the construction. The stone went down grade from crusher to mixer, and the concrete went down grade from mixer to forms, consequently the labor part of the concrete work was extremely low.

Should the force main, or the machinery below it, become temporarily disabled, we have a centrifugal pump which takes its suction from the raw water supply main. It will pump about 5,000,000 gallons daily and can drain these basins to almost their entire capacity so that almost their entire storage capacity is available in case of an accident to the station below. The pump is purposely small so that the reserve will last longer.

The clear water basin holds, when full, about 300,000 gallons. The settling or coagulating basins hold about 3,000,000 gallons. You may wonder at the small storage of clear water, but it is our intention to be able to manufacture clear water as fast as we need it, and we have spent our money rather to produce than to store. This was made necessary by the cramped condition of the location on which we had to build. If we keep our filters well ahead of our consumption we will anticipate no trouble.

For the ideas that make up the designs above described we have drawn freely from whatever source we could obtain, our idea of good engineering being the collection of all the best features obtainable, that are applicable, from whatever source they may be obtained honestly.

In the preliminary field work and collecting of data the writer was most ably assisted by Mr. M. D. Hayes and for him the station has been named the Hayes Station.

In the office work and designing, the largest and most able contributor has been Mr. Geo. W. Biggs, Jr., who has

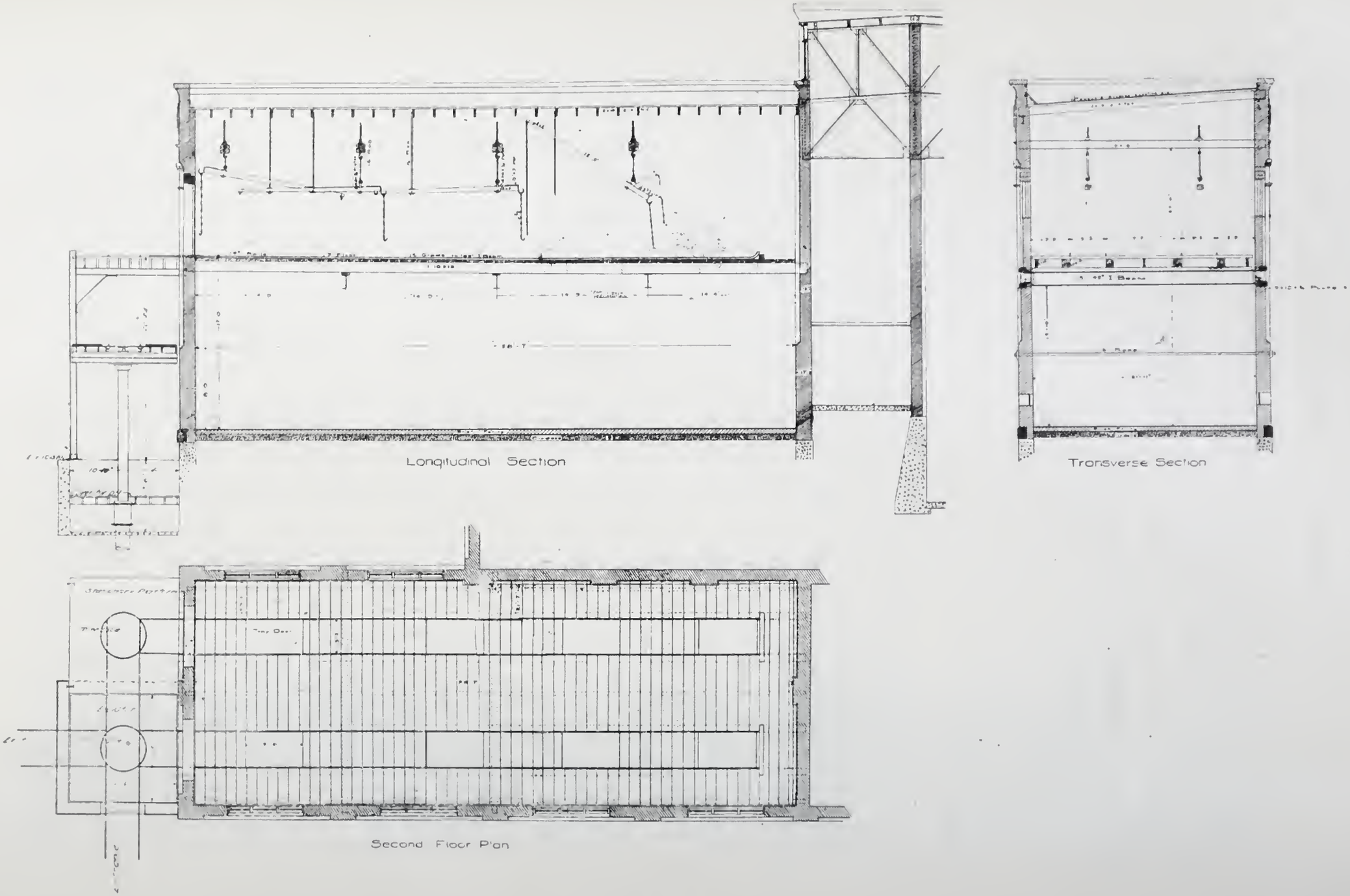

Longitudinal Section
Transverse Section
Second Floor Plan

FIG. 8.

worked out most of the details, and to him are creditable many features of the design.

With the exception of the superstructures, the brick buildings, the stack and the wash tank, the entire work, including the erection of the pumps, has been done by days labor by a plant erected and force organized by ourselves, and the heavy burden of this work has been borne by Mr. C. J. Eld Jr. the engineer in charge of construction, and to him must be largely credited the cost of construction as well as the remarkable progress made on this work.

Nor must we forget the executive and other officers of the American Water Works & Guarantee Company who have received our reports and have either adopted or modified our suggestions and furnished a great deal of the inspiration and all of the wherewithal by means of which the filter plant and pumping station has been erected.

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PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

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THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

*SUBMARINE CABLES.

THEIR CONSTRUCTION, LAYING AND REPAIR.

†H. C. SPECHT.
Non-Member.

In this paper I shall confine myself entirely to a description of the work connected with the construction, laying and repair of a modern submarine cable, and by way of illustration have chosen a concrete case, that of the Second German Atlantic Cable, with which work I was associated as an electrician. This cable connects Emden, Germany, with New York by way of the island of Borkum, the Azores (Fayal, a relay station) and Coney Island.

As is well known, a cable for the transmission of electricity consists of a metal conductor surrounded by insulating and protective material. The conductor of the Second German Cable was composed of several copper wires spirally arranged around a heavier one, in order to increase the flexibility and guard against breakage. Instead of copper wires, spirally wound copper strips might have been used, as was done in the case of the First German Atlantic Cable.

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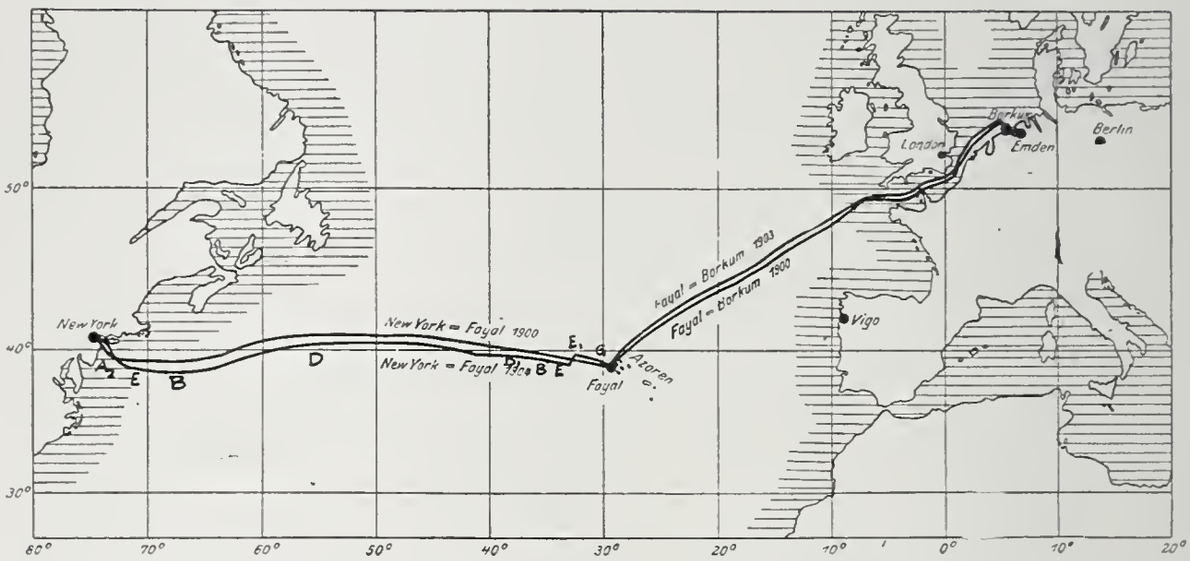
* Meeting of Society, June 19, 1906.
† 916 South Avenue, Wilkinsburg, Pa.

The insulation consists of guttapercha, a vegetable product and the only insulating material that resists entirely the disintegrative action of both fresh and salt water. The raw material is prepared and cleansed by kneading and washing in hot water, then a final cleansing is given by squeezing it under high pressure through fine sieves. This material is then pressed around the conductor in three distinct layers, each layer having a thickness of about .04 in., between each layer being a thin coating of resinous matter. Around this insulated conductor two layers of jute cords are wound to protect it from the pressure of the exterior cable casing, the latter con



Course of the German Atlantic Cables.

sisting of spirally wound iron or steel wires which have been steeped in a tar preparation. A final covering of jute cord or tape serves to hold the spirals together and, at the same time, give sufficient friction in paying out the cable. Wherever the Teredo occurs the conductor has to be protected by a winding of brass strips. In general, the type of construction for cables must be modified to suit the local conditions.

The coastal ends, where shallow water exposes the cable to a dragging or shifting action due to the motion of the waves or to the catching of ships' anchors, require a strong type of cable having a double armament of heavy iron wires. On some bottoms the cable will become more or less covered with

sand and thus partially protected, while a rocky or hard bottom gives much more trouble. The size of the casing wires as well as the slope of the spiral windings is adjusted to suit the various requirements.

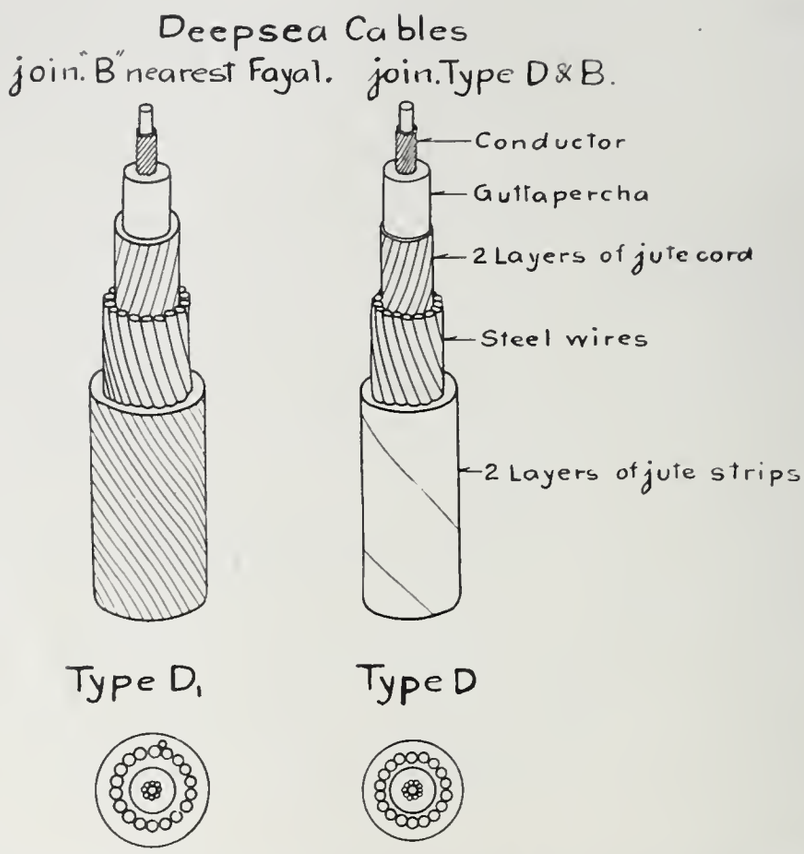
A type intermediate between the coastal and the deep sea cable is used to depths of about 350 feet, where the cable still is endangered by ships' anchors and especially by the fisherman, who have the habit of drifting with the wind with their anchors dragging along the bottom. The drag-nets of the modern fishing steamers are also a frequent source of injury.

In deep sea the cable is not subjected to the above dangers. Here, however, it must be constructed to withstand the high water pressure and the immense strains caused by its own weight during the process of laying and occasional lifting. The protecting wires are therefore made of the best kind of steel. The following table gives the dimensions and weights of some types used in the Second German Atlantic Cable:

	Coastal.	Shallow.	Deep Sea
Outside diam.	$2\frac{7}{16}''$	$1\frac{1}{2}''$	$\frac{29}{32}''$
Copper wires	1 x .108″	1 x .108″	1 x .096″
	12 x .036″	10 x .036″	10 x .032″
Iron wires	15 x .28″	10 x .28″	
	8 x .30″		
Steel wires			17 x .083″
Weight per nautical mile, tons	25.64	7.85	1.72
Max. tensile strength, tons	38.3	15.8	7.8

The whole cable was constructed in the factory of the North German Submarine Cable Works at Nordenham near Bremerhaven, Germany, and tested before and after each coating of guttapercha. In addition the deep sea type was subjected to a hydraulic pressure of about 7,500 lbs. per square inch corresponding to the water column it had to withstand. Around the unit core lengths two layers of jute were wound by machinery and the lengths were then joined together. The

core was then wound with its armament wires of iron or steel by a cable machine and over this cable two layers of jute cord or tape were wound. Finally the finished cable was soaked in a solution of tar. Thus cables were made of various lengths up to about 500 nautical miles. The finished cables were coiled into large iron tanks and immersed in water to prevent the hardening of the guttapercha. It is needless to say that



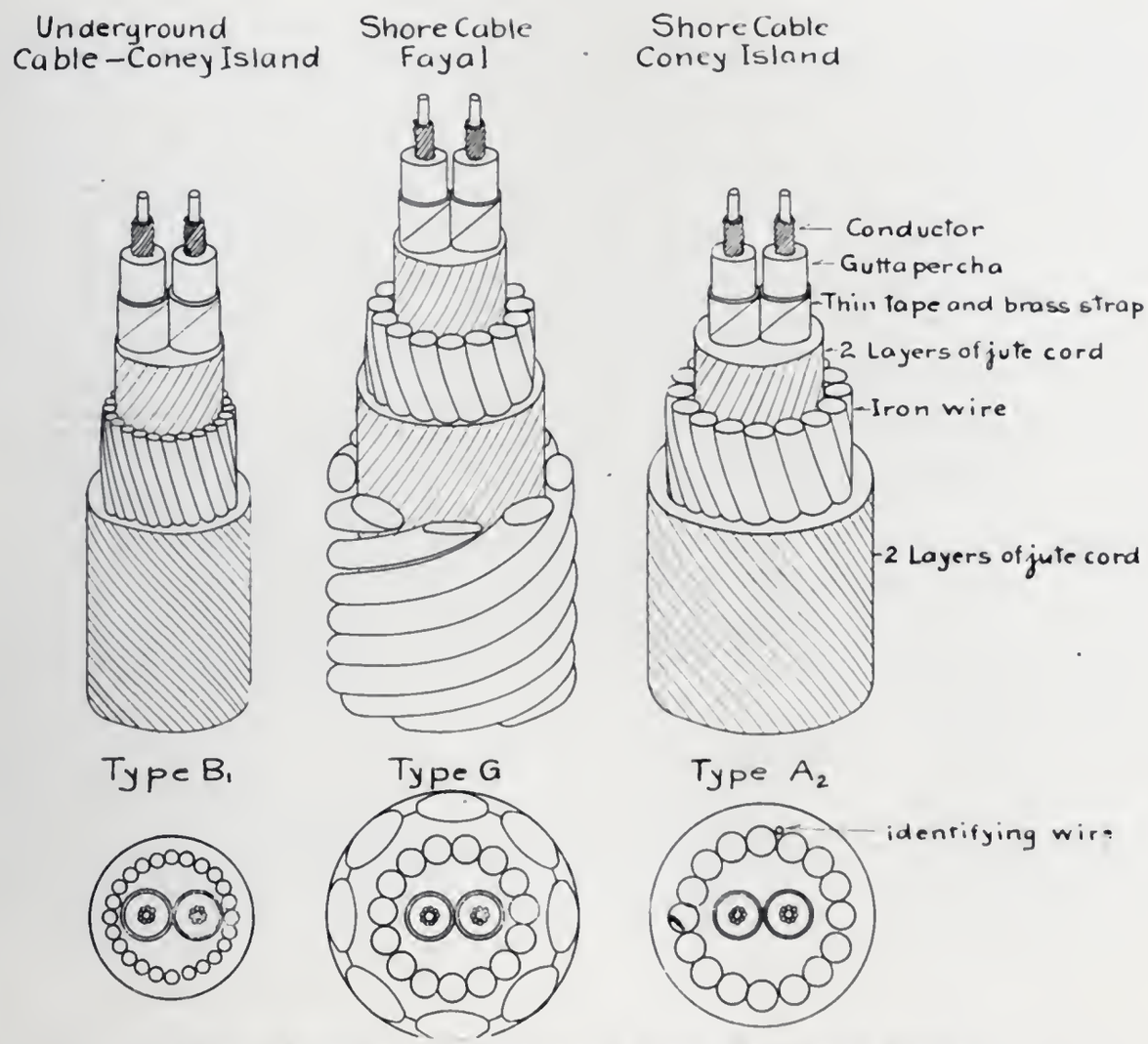
Types of cable used between New York and Fayal.

the cable is continuously tested during the construction, excepting when the core units are being joined, while every joint is subjected to a special electrical test.

After a sufficient quantity of cable for a trip is completed the cable is transferred by machinery into the tanks of the cable steamer. Two cable steamers were used which were especially built for cable laying and repairing. The smaller of the two, of English build, named "Von Podbielski," was used for laying the sections near the coasts. The larger one, "Stephan," was built at the Vulcan yards at Stettin, Germany.

The latter is the most modern steamer of its type and therefore I will give a short description of the essential features.

Externally the steamer resembles in every way a modern transatlantic liner, except it has a sheave at both bow and stern for paying out cable. Its length is 380 feet, beam 48 feet, draft 26 feet, displacement 9,825 tons, carrying capacity 5,000 tons of cable and 690 tons of coal. It is a twin screw



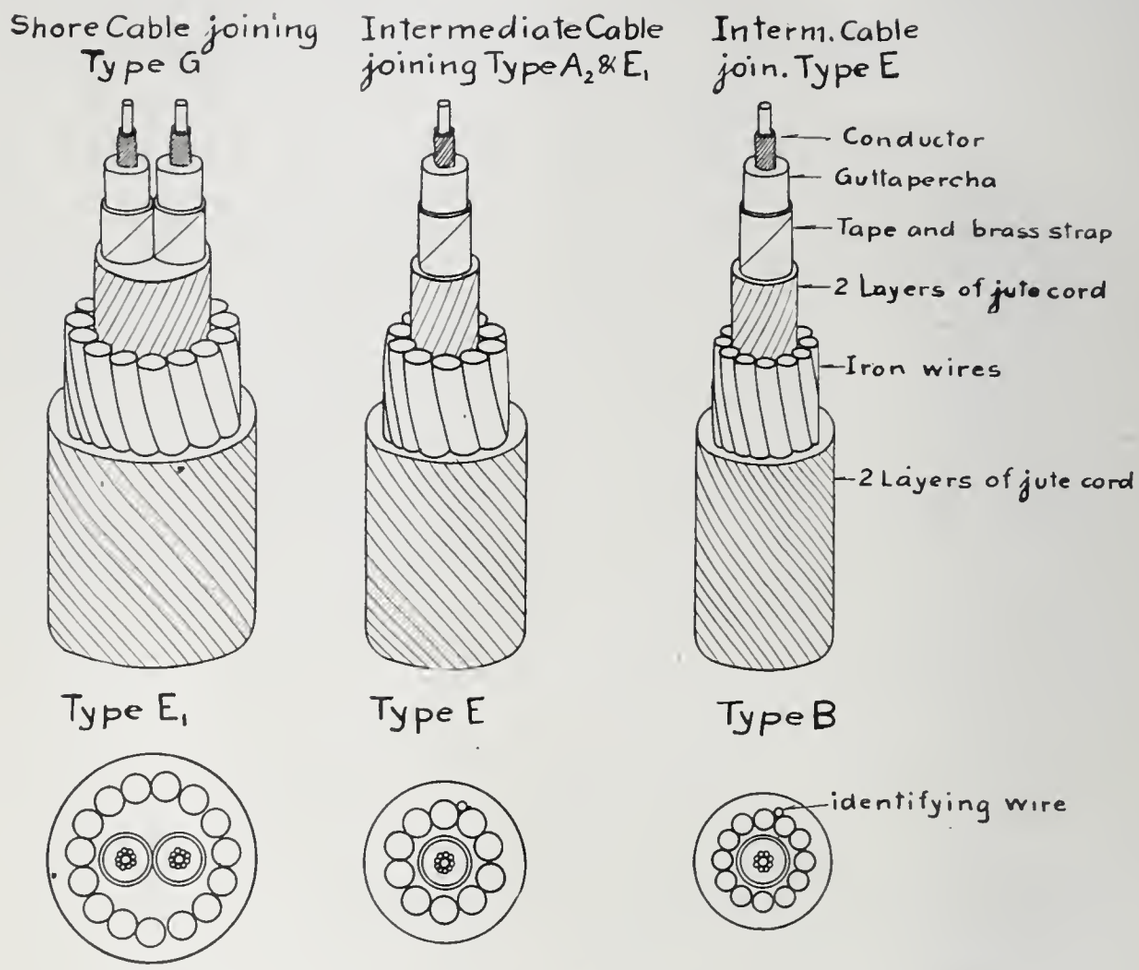
Types of cable used between New York and Fayal.

vessel, making it possible to steer at very low speed where the rudder cannot be used. The normal rating of the two engines is 2,400 horse power at 90 r. p. m. The trial speed was 13.8 knots per hour, the ordinary speed for laying cable varying from 6 to 11 knots per hour.

The hold contains the tanks for the cable. These are four in number and have a total capacity of almost 10,000 cubic feet.

Two of them have a diameter of 36 feet and the other two of 43 feet, their depth being about 20 feet. To prevent kinking a cone is built in the center of each tank. Incidentally these cones serve as reservoirs for drinking water. Three concentric rings of iron help to guide the cable in paying out. All surfaces of the tanks are made as smooth as possible.

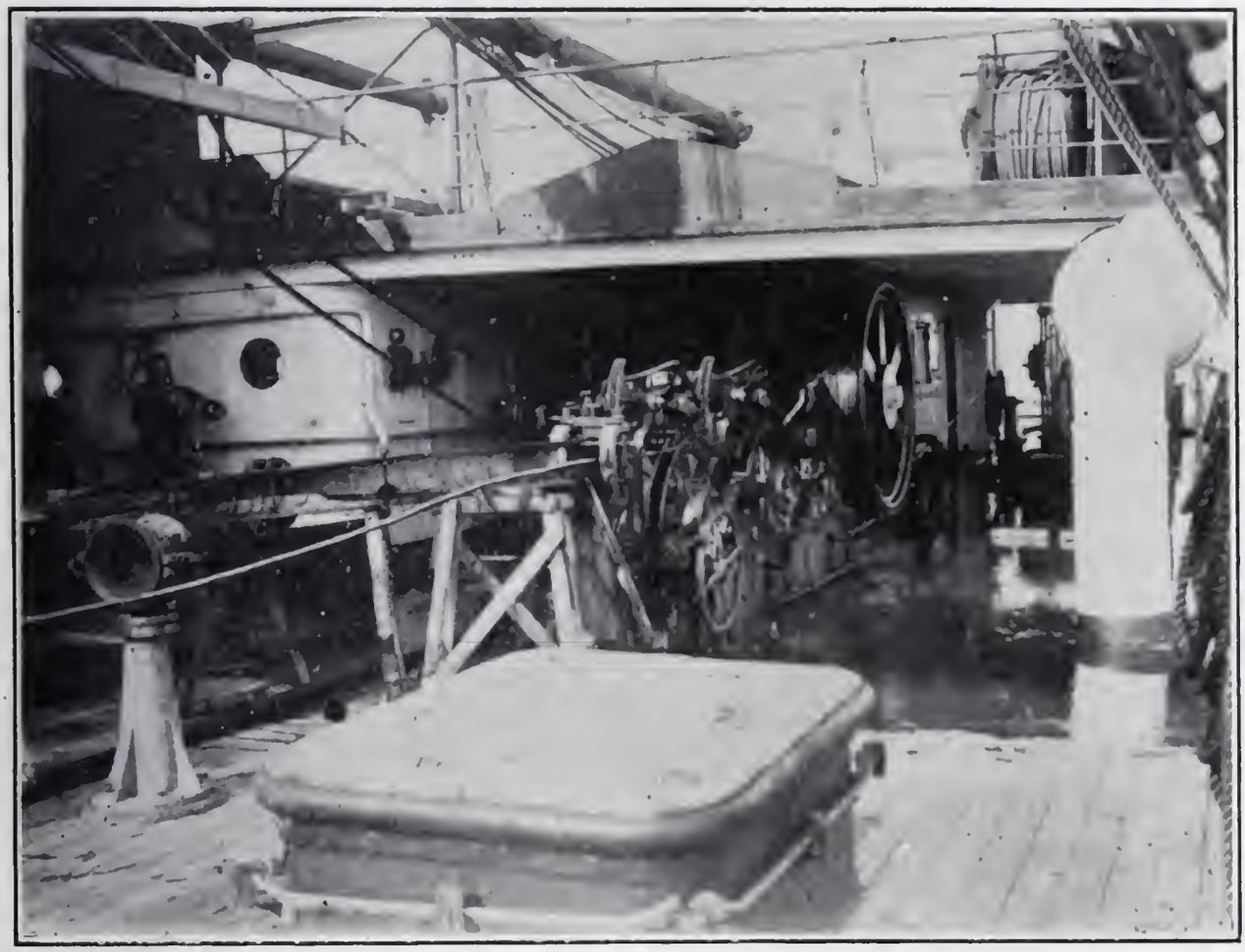
The machine for paying out the cable is situated on the after deck. It consists of a drum provided with heavy brakes



Types of cable used between New York and Fayal.

and geared to an engine. The cable is usually passed around the drum three times. A special engine is provided for drawing the cable from the tanks and also for starting up the "paying-out" machine after a splice has been made, after which the cable runs out into the ocean by its own weight. The cable passes from the tanks through various rings and guides to the drum and from there to the stern sheave over which it drops into the ocean. To measure the strain a dynamometer is placed between the drum and the stern roller.

On the starboard side of the "paying-out" machine is the office of the cable engineers. Therein is installed a device which gives the length of cable payed out; also the ratio of cable payed out to the distance traveled by the steamer in the same time, as the aim is to lay the cable in deep sea with not more than 6% of slack.



Paying out Machine.

The two machines for raising cable which has already been laid are situated on the forward deck. These two machines are similar to that on the rear deck, each being connected by gears to a steam engine. In this case the cables or ropes are guided by one of three bow sheaves of which the middle one has a "U" groove and the two outside sheaves a "V" groove. The tensions are measured here also by means of dynamometers.

A well equipped electrical laboratory is placed amidships. Here all testing and telegraphing is done. The records of passage and of cable laid are kept in a room near the bridge, where, on large maps, are plotted proposed course and actual course of the cable. Besides the main apparatus there are many auxiliaries, as, for instance, grapplers, steel ropes, chains, buoys, telephones between offices, sounding apparatus, etc.

Before laying a cable it is necessary to make a complete survey of the route by means of soundings and measurements of temperature. This had been done the previous year by the cable steamer, von Podbielski. It is interesting to learn that in the great depths of the Atlantic ocean the temperature was found to be always the same, about 34 °F.

The shore ends of the cable are laid by means of flat boats which can approach very near the beach, the landing being effected by buoying the cable with light floats and drawing it ashore by horses and man power into the cable house, where it is connected to the land system. After this has been done the sea end is sealed and made fast to an anchored buoy by means of chains and steel ropes. From here, after the exact bearings have been taken, the cable steamer starts its work. The cable is picked up and tested electrically and is then spliced to the end of the cable on board, and the steamer starts on its journey. From now on tests are made continuously. The necessary tests are as follows:

1. Copper resistance, which indicates a break in the conductor core.
2. Insulation test, which shows defects in the insulation.
3. Capacity test, which is a check on each of the above.
4. Continuous insulation test, similar to that of No. 2.

This last test is of more interest than the other three because it is being continued throughout the whole time of laying of the cable, thus giving a continuous record of the condition of the insulation. As readings are taken at frequent intervals, both on ship board and at the other end, each party has at all times a means of knowing that the other is attending to duty. When one wishes to telegraph to the other a method

of signaling is used whereby that desire is indicated. By reference to Fig. 1 the method for each may be explained. The diagram represents the connections for making the continuous insulation test, *i. e.* test No. 4. The battery at A is thrown into circuit through the reversing key. The deflection of the galvanometer is recorded, subsequent readings being taken at intervals of about one minute until the deflection becomes more constant. B, who has been notified to prepare for the continuous test, disconnects his telegraph instrument and connects in the condenser. His galvanometer readings are then

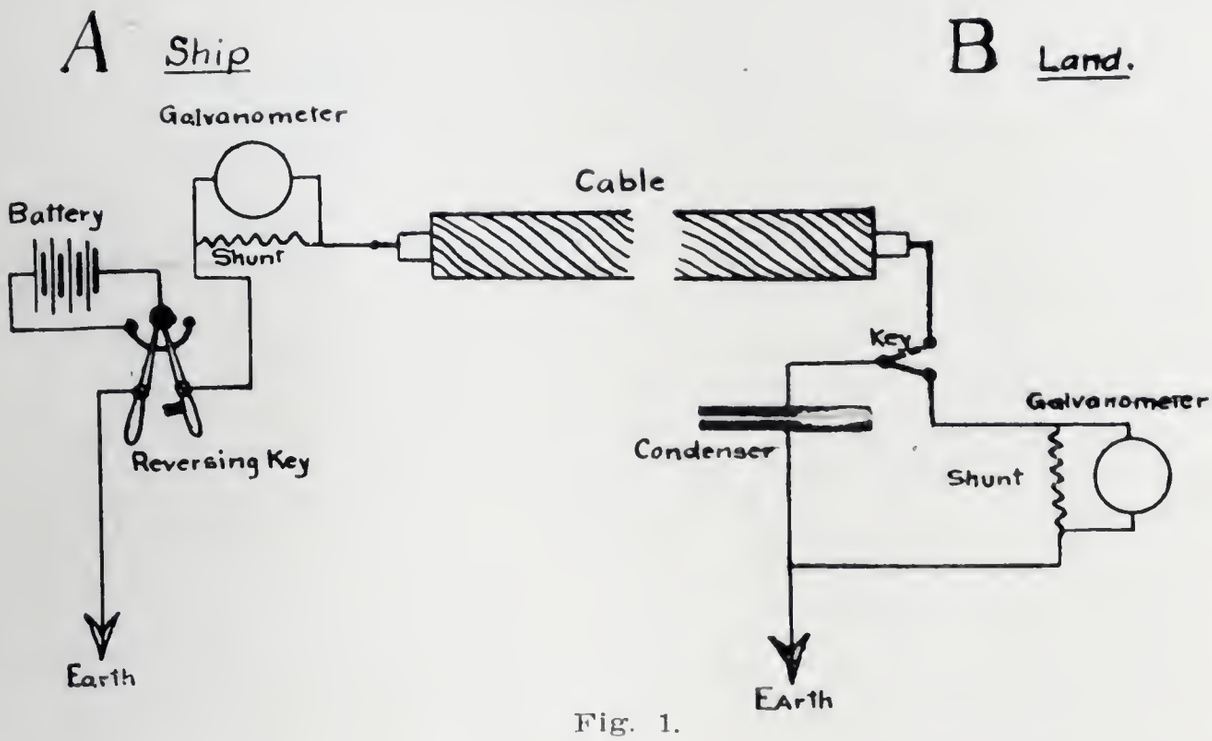


Fig. 1.

obtained by successively charging the condenser from the cable and then discharging through the galvanometer by means of the key at intervals of 5 minutes. The charging of this condenser causes a noticeable deflection of the galvanometer at A, hence should B at any time desire to be in telegraphic communication he has but to repeat this process at intervals of perhaps 20 seconds, the signals are noted by A who then changes his cable connections over to the telegraph instruments. On the other hand, should A desire to communicate with B he has but to disconnect his battery, whereupon B will note a diminution in the charge of his condenser thru the

decrease in galvanometer deflection. B understands the signal and immediately connects in his telegraph instruments.

During the laying of the cable every man has his respective duties, there being the customary three watches, so that each one has four hours on and eight hours off duty. In this way the laying of the cable proceeds day and night, systematically and without interruption, unless accidents occur.

Cable laying in deep water is carried on in the same manner as in shallow water, with the exception that more trouble is experienced in every operation. The brake must be carefully regulated to maintain a proper tension on the cable that the strain may be kept within a safe limit. Deep sea cables are also more susceptible to kinks because of their being lighter and more flexible. This is something that must be carefully guarded against, as owing to high pressure and great tensile strain concentrated in deep sea work, any small defect in the cable may result in eventual electrical and mechanical failure.

In deep sea work an accurate record of distance traveled was obtained from a device towed from the stern of the ship which registered the number of miles traversed. This record, taken simultaneously with the record of the length of cable payed out, gives the amount of slack in the cable. This method is equally serviceable in fair and bad weather, whereas solar and stellar determinations for bearings are permissible only in fair weather.

With this brief explanation of the construction and laying of the cable it will no doubt appear to many to be a simple task, but in addition to the few serious difficulties mentioned, there are many minor troubles which result in great loss of time and money.

In locating a fault in a cable, electrical tests are made, the methods varying in different cases. In the case where two cables connect the same stations and a fault is noticed in one, the most accurate test is by the simple loop or Wheatstone bridge method. In this test there are three known resistances and one unknown resistance. This resistance, together with the distance from the station to the fault, being calculated

from the observed data. This test may be made at both the stations and if the results check the fault is immediately located. More difficulty is involved if but one cable connects two stations. The tests to be applied are not as accurate as those applied in the case of two cables and, moreover, depend to a great extent upon the intelligence of the tester.

As soon as the fault is located, a cable steamer with the necessary tools and repair cable is dispatched to the scene.

Forward deck of cable steamer.

After determining the location a sounding is made and one or two buoys are anchored nearby, thus giving the vessel her bearings with respect to the cable at all times regardless of the weather. If the water is shallow at this point little trouble is experienced as the cable can easily be picked up, but in some cases the depth of water may be several miles, so that great trouble is experienced. The general mode of procedure in connection with deep sea repair jobs is as follows:

The ship withdraws several miles from the cable route, a "Lucas" anchor is then slowly lowered by means of chains and steel ropes, this consuming about 6 or 7 hours for a depth of 2½ nautical miles. The ship then proceeds to cross the course of the cable and the instant the anchor hooks the cable an increased tension is observable on the dyanometer.

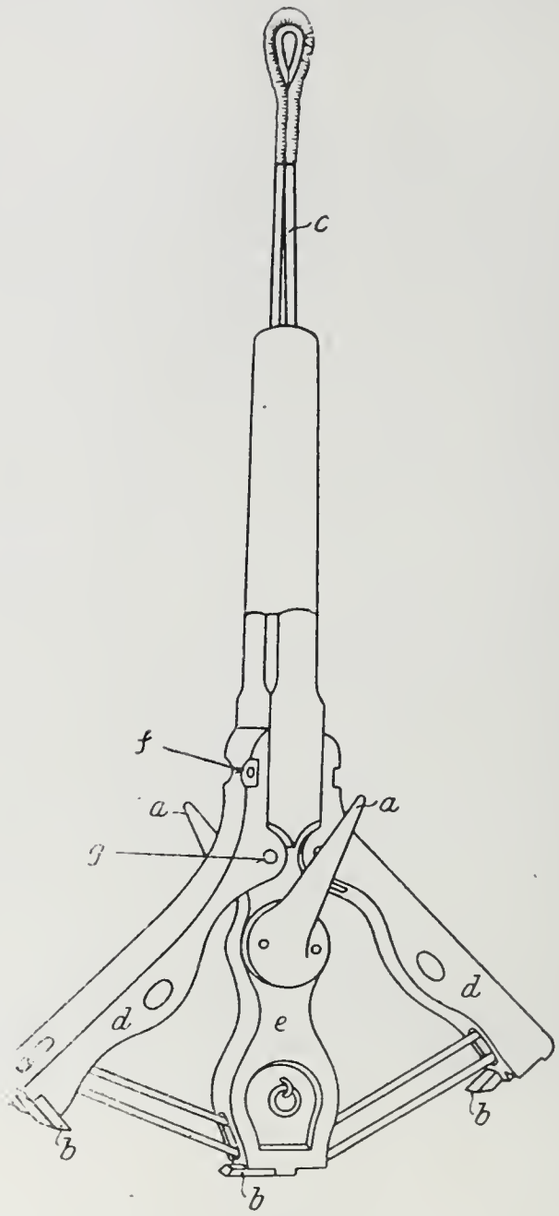
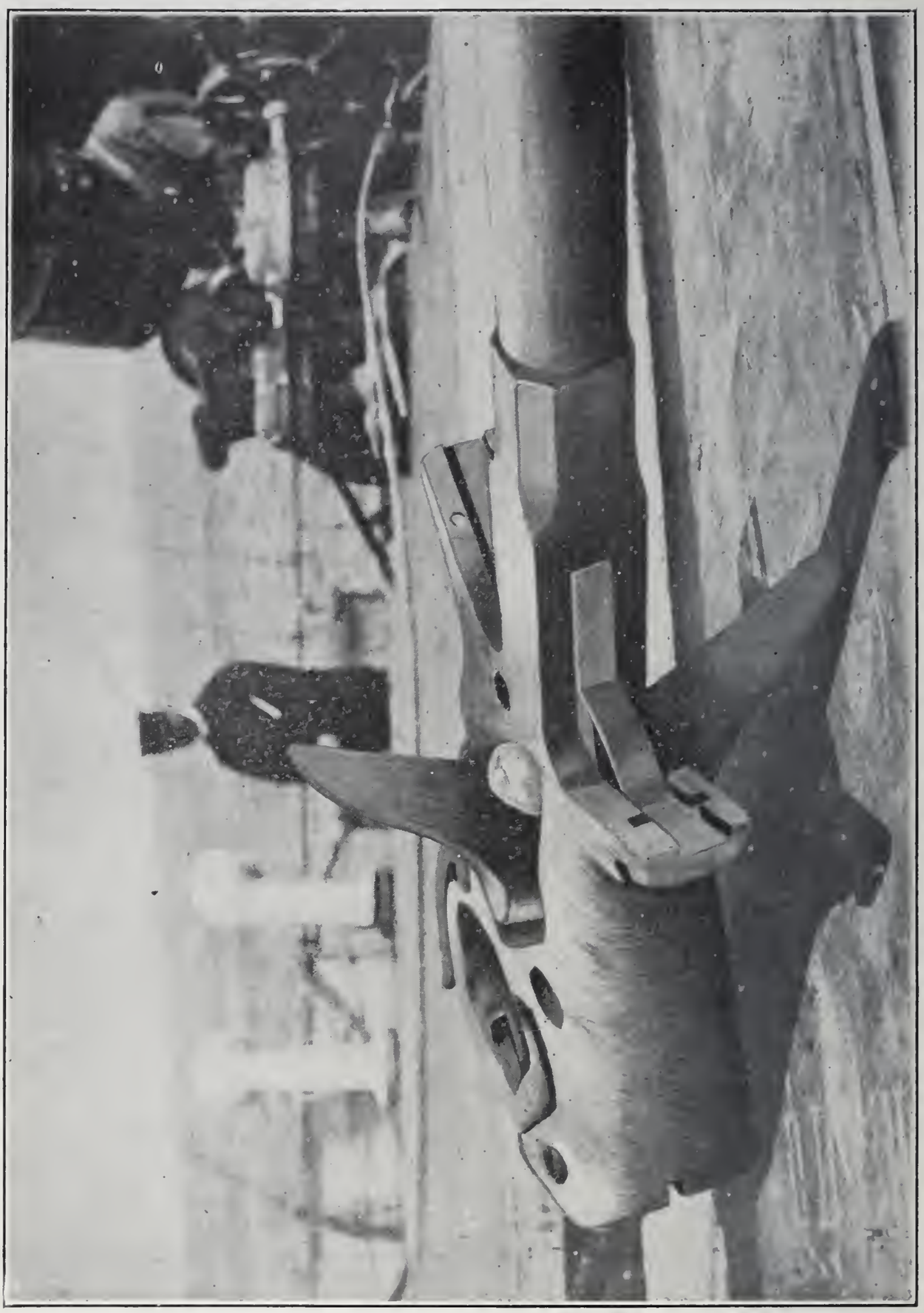


Fig. 2.

Referring to Fig. 2, the principle of operation of the "Lucas" anchor is as follows: The supporting cables C pass through the shaft of the anchor and over rollers to the arms d d, which are hinged at g, but normally prevented from coming together by two bolts at f, these bolts having a carefully predetermined cross section and breaking strength. The

anchor, in dragging, picks up the cable by means of one of the hooks a a and the increasing tension on the anchor ropes finally causes the two bolts f to fail, thus allowing the arms to close down on the cable which is looped around the hook a. b b are knives arranged diametrically opposite so that whichever hook picks up the cable will cause it to be firmly grappled and cut on one side only.

The loose end falls to the bottom, while the other, being held fast by the anchor, is raised to the surface at the rate of a ¼ mile an hour, this speed producing about the maximum tensile strain that the cable will stand. After hauling the cable on board telegraphic communication is established with land and then the necessary tests for the defect are made. If the cable is found intact it is buoyed and the vessel proceeds about 2 miles beyond and picks up the other end. This time the cable is grappled and raised by means of an ordinary grappler, there being enough slack at the free end to allow this being done. The tests previously described are now made on this section and if the fault is found to be not over 15 or 20 miles distant it is advisable to continue hauling in instead of grappling and cutting the second time. When the fault is located this section is discarded and replaced by a new section of cable between the fault and the end first raised. At the point of splicing a loop is made to relieve the splice from tensile strain. The splice at the fault being completed the new cable is payed out while the ship returns to the spot where the end first raised is buoyed. Both land stations are now notified to prepare to communicate with each other at the end of a given length of time, which is deemed sufficient for the final splice to be made. The final joining and looping of the cable being completed it is lowered some 50 to 100 feet and, as the last move, the rope is cut. This is a festive act and is attended with considerable ceremony, the meaning of which will be appreciated when it is understood that the time consumed in the repair of one fault may be as long as six months. The most troublesome factor is, of course, unfavorable weather which is repeatedly of long duration.



Lucas anchor with stone accidentally lodged near hook, which prevented the proper operation of anchor. On this occasion the cable was cut, lifted and then just before hauling on board was lost by slipping over the stone.

In conclusion, allow me to suggest that there is still a great opportunity for the United States, Germany, France, etc., in the matter of submarine cable service. It is possible that it is not generally appreciated that of the approximately 230,000 miles of submarine cable in service England owns about 62%, the United States 17.5%, France 8%, Germany not quite 6%, and Denmark 3%.

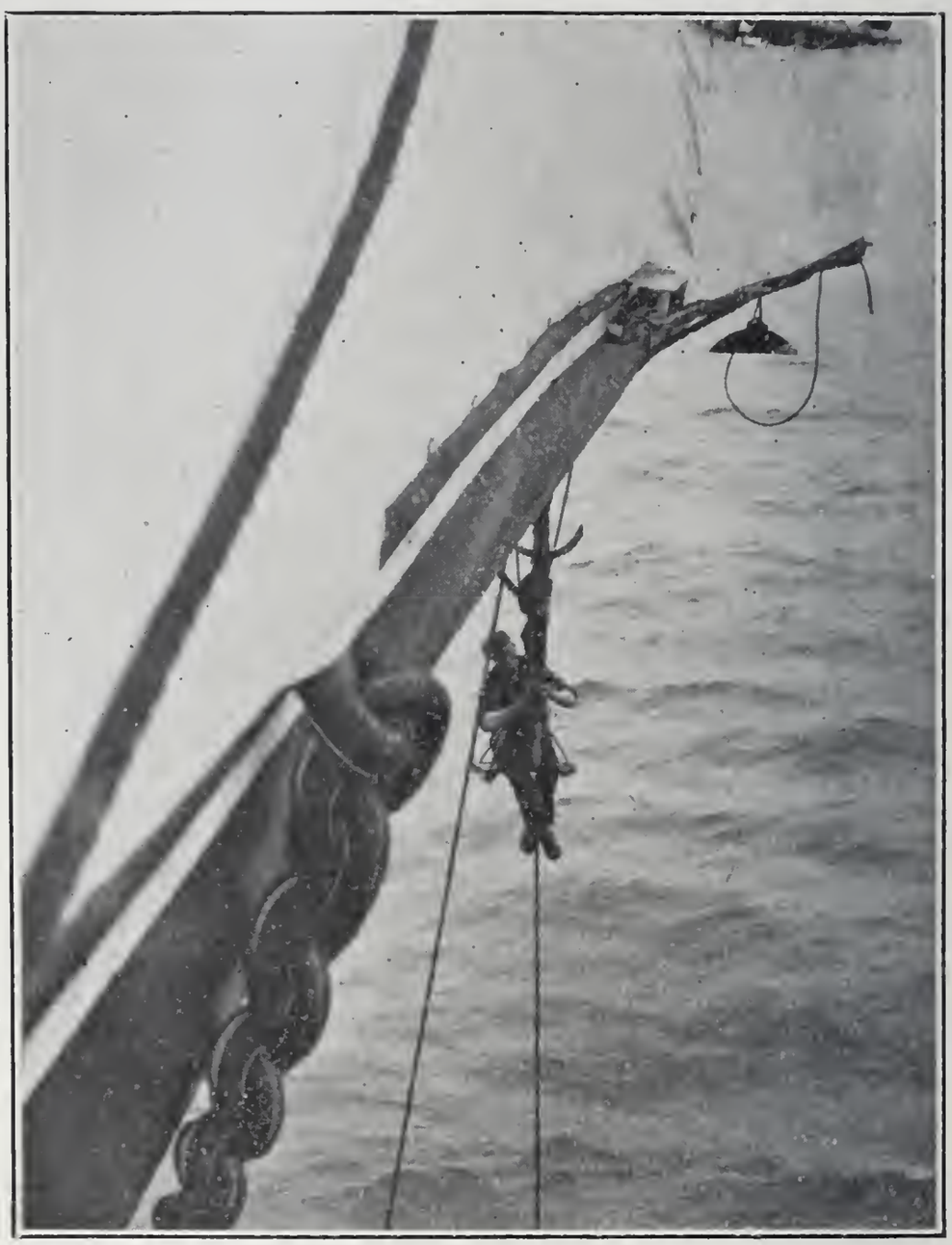
Submarine cables have a political as well as a commercial value to the country under whose control they are operated. Cable projects have generally been backed by private capital, except in France whose cables are largely owned by the government. These projects, however, are always subject to government sanction, its messages being given preference over all others and it taking entire possession in time of war. England, through her nearly 140,000 miles of cable, is in direct and, if necessary, exclusive communication with each and all of her colonies. Consider, for example, the case of the Boer War where all news passed through a censorship at London before being given out to the world, thus being subject to revision or to entire suppression if deemed desirable by the authorities. As to their commercial value, let us assume, for instance, that a German colony is undergoing a financial depression. The first news therefrom is received by English cable, thereby giving her financiers the advantage of time over those of the country more deeply concerned.

That they are paying investments notwithstanding their great cost has been demonstrated repeatedly, notably by the Pacific cable from the United States to the Philippines, which has been in service not more than three years.

The Second German Atlantic Cable was the first large cable to be laid exclusively by a German company, and it seems very creditable that the North German Submarine Cable Works accomplished their entire work of construction and laying with less delay and greater ultimate success than had hitherto been experienced in connection with any previous project of equal magnitude.

It is to be hoped that such evident success in the develop-

ment of methods will be recognized by private capital and government authorities both here and abroad, thus opening the way for the further interconnection of the several nations and their acquisitions that is demanded by their present rapid development.



Deep sea cable raised by an ordinary grappler; preparing to remove cable from grappler.

It does not seem probable that the inventions of the last few years in the field of wireless telegraphy will materially affect the demand for more extended submarine cable service, for with all the successes of these later innovations, each

system has its limitations which confine it to its own distinctive field of usefulness; for ordinary commercial communications the cable has nothing to fear from wireless telegraphy.

In closing I desire to express my obligations to Messrs. E. R. Spencer and B. A. Boyd for the assistance kindly extended to me in the preparation of this paper.

DISCUSSION.

H. W. Fisher, Member—How low can the resistance of a fault be before the cable has to be put out of service, and how low may be the resistance at which the cable could still be operated?

H. C. Specht—According to my experience, a cable 2,000 nautical miles long, having 600 megohms insulation resistance per nautical mile and 3 ohms copper resistance per nautical mile, will give satisfactory results if the simplex system and recorder (telegraph apparatus) are used. It is possible to telegraph through a cable with a great deal lower insulation resistance if a higher voltage is used with sensitive instruments. It is even possible to send messages through a long cable with a fault of only a few ohms resistance to the ground if very sensitive telegraph instruments are used and the fault be located near the sending station. However, a message could not be received at this station.

There are so many minor factors, such as electrification of the cable, induction, etc., which affect telegraphing through cables with low insulation resistance, that no exact figures can be stated.

H. W. Fisher—How low could the resistance be for successful operation of duplex telegraphy?

H. C. Specht—I cannot give exact figures, but an experienced telegraph operator once told me that a fault of as high a resistance as 100,000 ohms would forbid the use of the duplex system.

H. W. Fisher—Guttapercha offers a very high resistance to voltage tests. It takes about 40,000 volts to break down

$\frac{1}{10}$ of an inch. How high a voltage could you apply without breaking down a cable?

H. C. Specht—I believe it is almost impossible to give a satisfactory answer to this question. My experience has been that guttapercha, as an insulator against high voltage, is as uncertain as is the mechanical elasticity of rubber. A break down may occur in guttapercha insulation, $\frac{1}{10}$ in. thick, at as low as 5,000 volts, but it may just as likely stand 30,000 volts or more. When there is a small fault in the insulation the breakdown may not occur at this weak spot. I remember some cases where the faulty cables were placed under high tension, but it was impossible to break the faults down. They were then subjected to a low voltage of very low frequency and the faults broke down.

J. W. Smyth, Member—What method do you use in insulating your conductors and how thick is the insulation?

H. C. Specht—The process is very similar to the tubing process by which lead cables are armoured. The conductor is run through an orifice of conical shape with equal clearance all around the wire. The guttapercha, which is kept in a plastic state, is forced under pressure through this clearance space around the conductor as it is drawn through. Each layer is three to four hundredths of an inch thick and there are generally three layers. After each coating, tests at 75° F. are made. Sometimes tests are made only after the first and third coating.

J. W. Smyth—What method do you use for testing the sections of cables after you have tested each conductor?

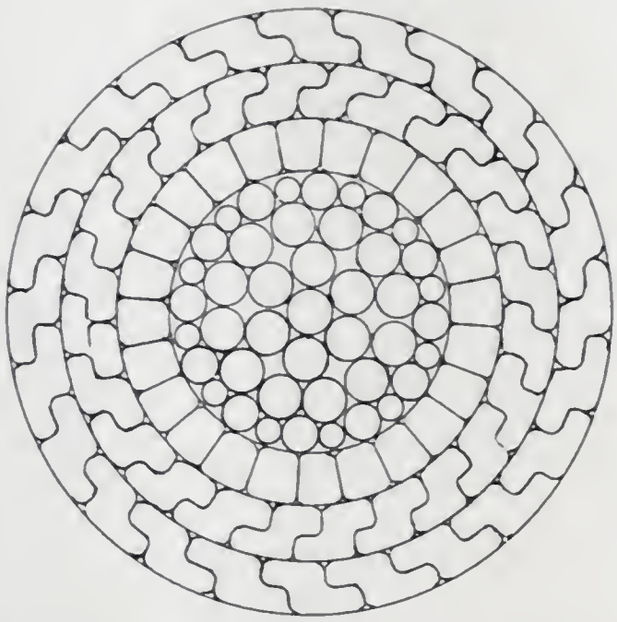
H. C. Specht—Twice each day a complete set of tests are made including copper resistance, capacity and insulation tests. While the cable is passing through the cable machine it is kept continuously under insulation test so that any fault may be at once detected and remedied. This test has to be interrupted when a joint is made and so a special test is made for the joints. It takes about an hour and a half to make a joint and cool it off.

T. C. Smith, Non-Member—What voltage is used in the transmission of cablegrams?

H. C. Specht—We used thirty volts for the recorder on a

line approximately 2,000 nautical miles in length and I believe this voltage is also used at regular telegraph stations.

K. A. MUELLENHOFF, Member—Are cables ever protected by using wire of a peculiar shape such as is shown here? Such



cables are used for mines, cableways, bridges, etc. I should think these "closed" cables would give greater protection to submarine cables than the ordinary armor, as small stones could work in between the round wires and injure the insulation. They are manufactured by Felten & Guilleaume at Muhlkeim, the same firm that holds the controlling interest in North German Submarine Cable Works.

H. C. SPECHT—As far as I know only round armament wires are used for submarine cables and no trouble is experienced. Such protection would only be required in very shallow water near the shore, and here the armament is made extra strong to withstand such action.

The peculiar shaped wires referred to are used for some kinds of cables, but they would not be practicable for submarine cables because the cable would be too stiff.

S. M. KINTNER, Member—When a cable is cut and the unprotected end left lying in the ocean does moisture travel any distance in it?

H. C. SPECHT—It is hardly possible that the moisture will pass into the cable, because the conductors, which consist of

several copper wires, are soaked with a compound material composed of wood-tar, guttapercha and resin, before the guttapercha is pressed around the conductor. Even if the moisture worked into the cable for a short distance it would do no harm for several feet are always cut from the end before splicing. When the cable end is being buoyed it is sealed with gutta-percha and a steel cap is placed over it for protection.

S. M. Kintner—How many conductors are used in a cable?

H. C. Specht—Only one conductor is used. I believe it is impossible to lay and repair a deep sea cable with more than one conductor, because of the mechanical strain.

In shallow water cables have been laid with more than one conductor, sometimes 3 or 4. In the two German Atlantic cables the shore and underground types are made of two conductors. In the ocean the end of this second conductor is connected to the armament wires giving a good contact to the earth and neutralizing any inductive effects of neighboring cables near the shore.

H. W. Fisher—Rubber has been used in this country for insulating cables along the coast for distances of about one hundred miles. We have made considerable of it for the government for coast defense purposes and signal purposes, and it seems to be giving pretty good service, some of it having been in service for five years. I think rubber is all right for harbor work, though of course it has not had a long trial, but there are doubts of it being able to withstand the high pressures encountered in deep sea work.

H. C. Specht—Have they used a special rubber?

H. W. Fisher—It is probably 30% rubber; you have to use 60 to 70% of a chalky material.

H. C. Specht—It would be a great advantage if rubber could be used, because it is much cheaper and much easier grown than is guttapercha. A rubber tree is productive after six years and yields its product again and again. A guttapercha tree when fifteen years old will yield only thirteen hundredths of a pound of guttapercha per year and when one

hundred years old the product of the tree is only from two to six pounds and the tree has to be cut down to obtain the guttapercha.

For one nautical mile of the Second German Atlantic cable there is used about 250 pounds of guttapercha, the ratio of the weight of guttapercha to copper in the cable being approximately 2 to 3. Hence it is seen that guttapercha is a very important factor in the cost of submarine cables. The submarine cable companies are looking for a cheaper material and are beginning to realize the guttapercha supply will sooner or later be exhausted. Because of this several of the governments have recently been planting new trees where the old ones were cut down.

Even if the rubber remained good for only five years, it would still, in many cases, be an advantage to use it, because the profit on submarine cables is so high that in a few years a cable would more than pay for itself.

J. D. Klindworth, Non-Member—What is the cost of an Atlantic cable?

H. C. Specht—The cost of the cable from Germany to New York was about $5,000,000, including both manufacture and laying.

A. Stucki, Member—Could not wireless telegraphy be used to simplify the laying of a cable? You could use it for communicating between the ship and the shore and not have to interrupt the work in order to use the cable.

H. C. Specht—It has been done, though we did not have the apparatus on board at that time. It would generally be a help, but the wireless apparatus is at times liable to interruption itself. Suppose there is a thunder shower, how does it affect the wireless system? How much time would it take to overcome the charges in the air?

*GAS DRIVEN ELECTRIC POWER SYSTEM.

As Exemplified in the Warren & Jamestown Railway System.

†J. R. BIBBINS.
Non-Member.

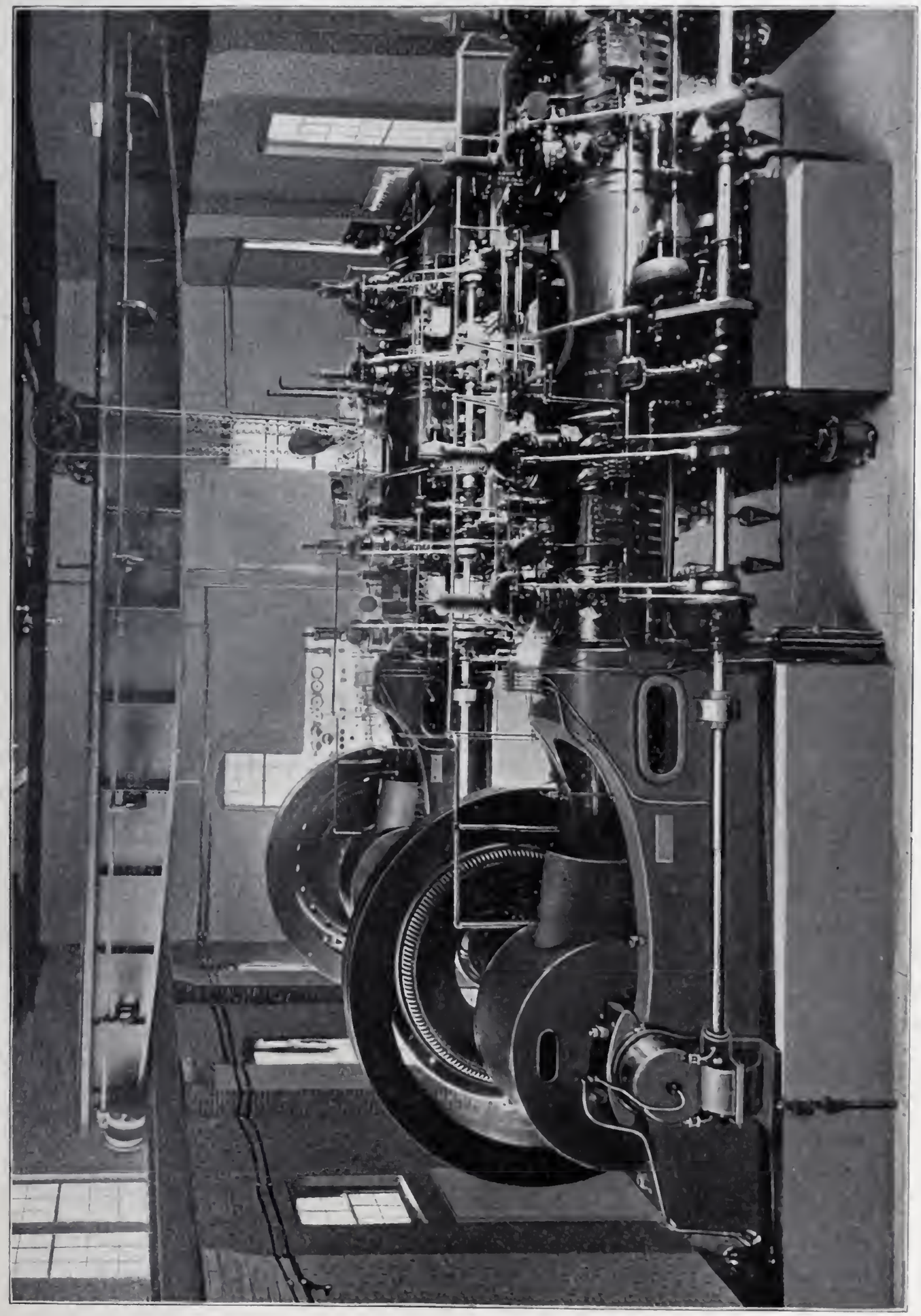
The special character of this paper results from the skepticism which prevails more or less even today regarding the ability of a gas power plant to do the work that has formerly been done by steam power; and in presenting a paper on some phase of the gas power question, the author has chosen the practical rather than the speculative, believing it to be of more general interest. In the final showing, questions of plant design all merge into that of successful operation, which is the commercial criterion by which the power plant as a whole is appreciated.

In the unusually severe conditions surrounding the power service at Warren a most convincing example is found of the subject under discussion, and this point, together with the fact that the Warren plant is the only one of its kind in existence today, has justified, to the author's mind, the citation of specific experience. Primarily the paper deals with the gas power plant, although some essential features of the electric railway system are incidentially mentioned.

GENERAL SYSTEM.

To obtain a correct idea of these conditions at Warren it is necessary to review in perspective, as it were, the main features of the system as a whole, embracing not only the power plant but also the distribution system, road bed, equipment and traffic. These subjects are outlined briefly in the Appendix. It is sufficient to say here that a gas engine plant of 1,000 horse power capacity, in two units, is operating, with-

* Mechanical Section, June 5, 1906.
† 226 East End Ave., Pittsburgh, Pa.



General Interior View of Main Power Station, showing two 500 H. P. Gas Engine Units operating in parallel on regular railway load.

out steam reserve, an entire railway system totaling 42 miles of road, half city and half interurban. The latter traverses a difficult country with but 2 to 4 cars in service, all of unusual size (35 tons), high speed (50 miles per hour) and powered 200 horse power per car. Upon this plant, which regularly operates 80% to 90% of the time, the entire traction service of an important community depends.

POWER HOUSE EQUIPMENT.

Location—Stoneham, Pa., near Warren.

Capacity—A. C.—2 500 H. P., 300 Kw. gas engine units—600 Kw.
Reserve Plant—D. C.—3 275 H. P. gas engines belted to 200 and 150 Kw. generators—550 Kw.

Converting Capacity—One Rotary Converter—300 Kw.
D. C. Storage Battery Auxiliaries—265 cells Gould battery, with booster.

Main Plant.

Dimensions of engine room—68¼x47½ ft.
Overall dimensions Main Unit—42′ long x 16′ 9″ wide x 12′ high.
Area Engine Room—3240 sq. ft.=5.4 sq. ft per Kw.
Net area Unit—704 sq. ft. = 2.35 sq. ft. per Kw.
Spacing of Units center to center—19′ 1½″.
Clearance around units at piers—5′.
Style of Engine—Horizontal double acting tandem four cycle.
Maker—Westinghouse Machine Company.
Size of Cylinders—21″ diameter, 30″ stroke.
Diameter of flywheel—13′ 0″.
Normal Speed—150 R. P. M.
Rated Capacity—475 B. H. P.
Maximum Capacity (guaranteed)—525 B. H. P.
Generator Capacity rated—300 Kw.
Equivalent H. P.—430 B. H. P.
Overload Capacity of Unit—22%.
Ignition—Electric "hammer break," duplicate supply 80 or 100 volts.
Starting—Compressed air, storage pressure 240 pounds.
Governing—Oil relay system, "Hartung" centrifugal regulator.
Lubrication—Cylinder oil-force feed, engine oil, continuous gravity filtering system.
Cooling—Spring water, gravity, head 10 pounds pressure.

Type of Generator—Revolving field engine type solid coupled.
Characteristics—300 volts, 3-phase; 25 cycles, Westinghouse.

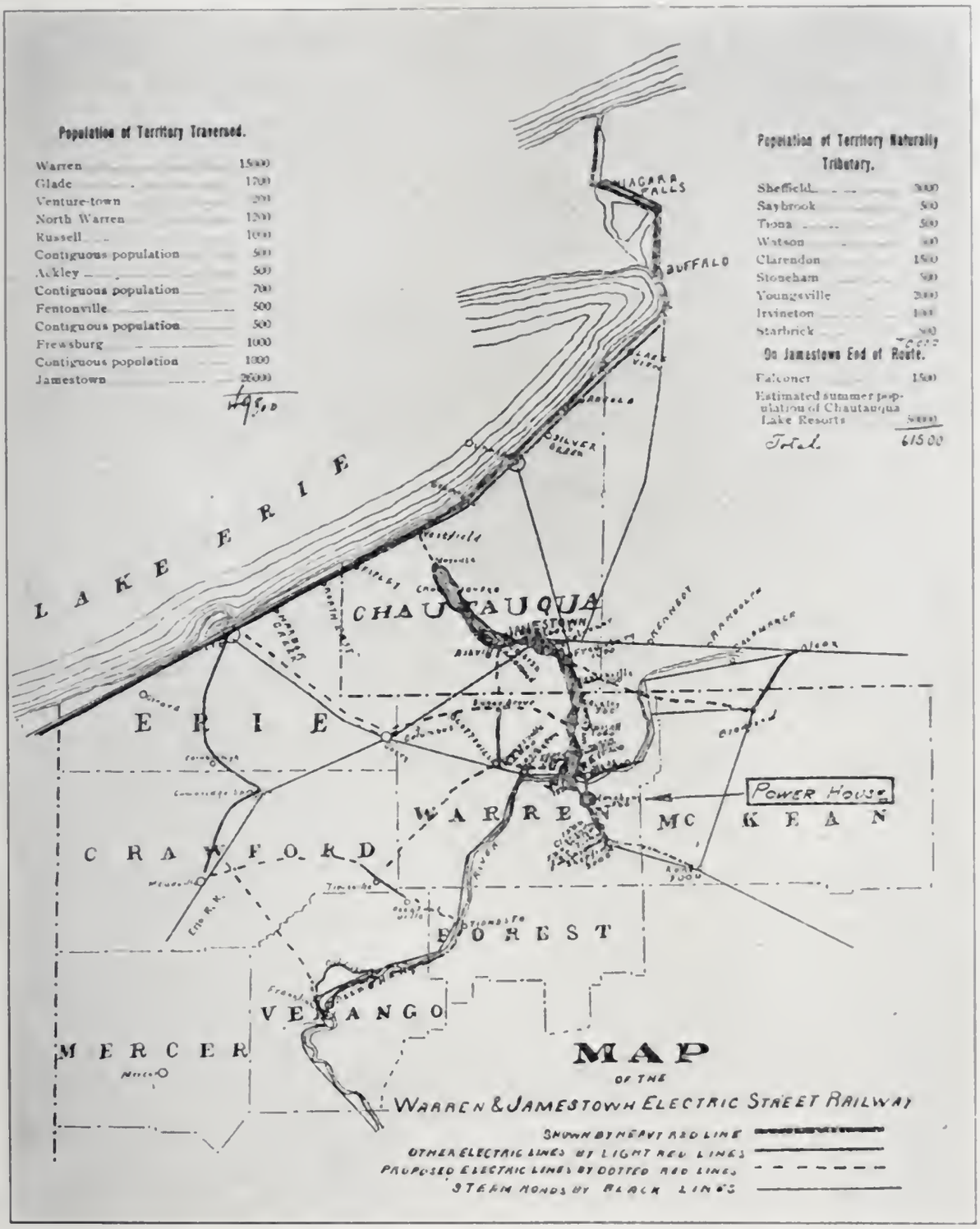


Fig. 7. Map showing country traversed by railway.

SPECIAL CONDITIONS OF POWER SUPPLY.

At the time of its organization, several years ago, the Warren Street Railway Company decided to experiment with gas power for running their direct current city system. Vertical single acting type gas engines were installed and the

results so greatly exceeded those possible with gas fired boilers and steam machinery as to fully warrant all power extensions in gas machinery. For the more important alternating current interurban service, a horizontal double acting type gas engine was chosen in view of the heavy duty that would be imposed upon it. In the operation of the direct current urban system a storage battery was at all times available, not only to take care of emergencies, but to assist in the more uniform loading of the power equipment. With the alternating current interurban service, however, such a reserve, although much needed, was evidently not available; the new power equipment must not only sustain the load unaided, but also render a service proportionately more certain owing to the danger of isolating passengers in midcountry. That it has accomplished this result is shown by the records of practically uninterrupted operation of 18½ to 24 hours per day, including Sundays, and a complete tie-up of the system has yet to occur traceable to gas engine trouble alone.

With a definite operating schedule the load demands may, in a sense, be anticipated; for instance, when starting on the even and half hour from terminals. But practically, it is impossible to anticipate their extent, with the result that maximum generating capacity must be kept continually in service, although at one time the load may fall to practically nothing and at the next instant rise to the limit of the plant capacity. It is difficult to convey on paper an adequate impression of the severity of a load like this, and the author can only say that of all the power plants which he has been privileged to witness in operation, none have even remotely approached this railway plant, with perhaps the exception of a steel works rolling mill load.

Some idea may be obtained from the accompanying load diagrams (Fig. 1), which show the actual movement of the mixing valves on one of the gas engines to accommodate the changes in impressed load. Even these do not represent the very worst conditions, for it frequently occurs that cars become "bunched," particularly during the summer months when

holiday traffic is usually heavy, taxing the entire system to the utmost.

These diagrams were taken by moving a strip of metallic coated paper at uniform speed in contact with a pencil attached to the valve motion. This motion is rectilinear and proportional to the amount of gaseous mixture admitted to the cylin-

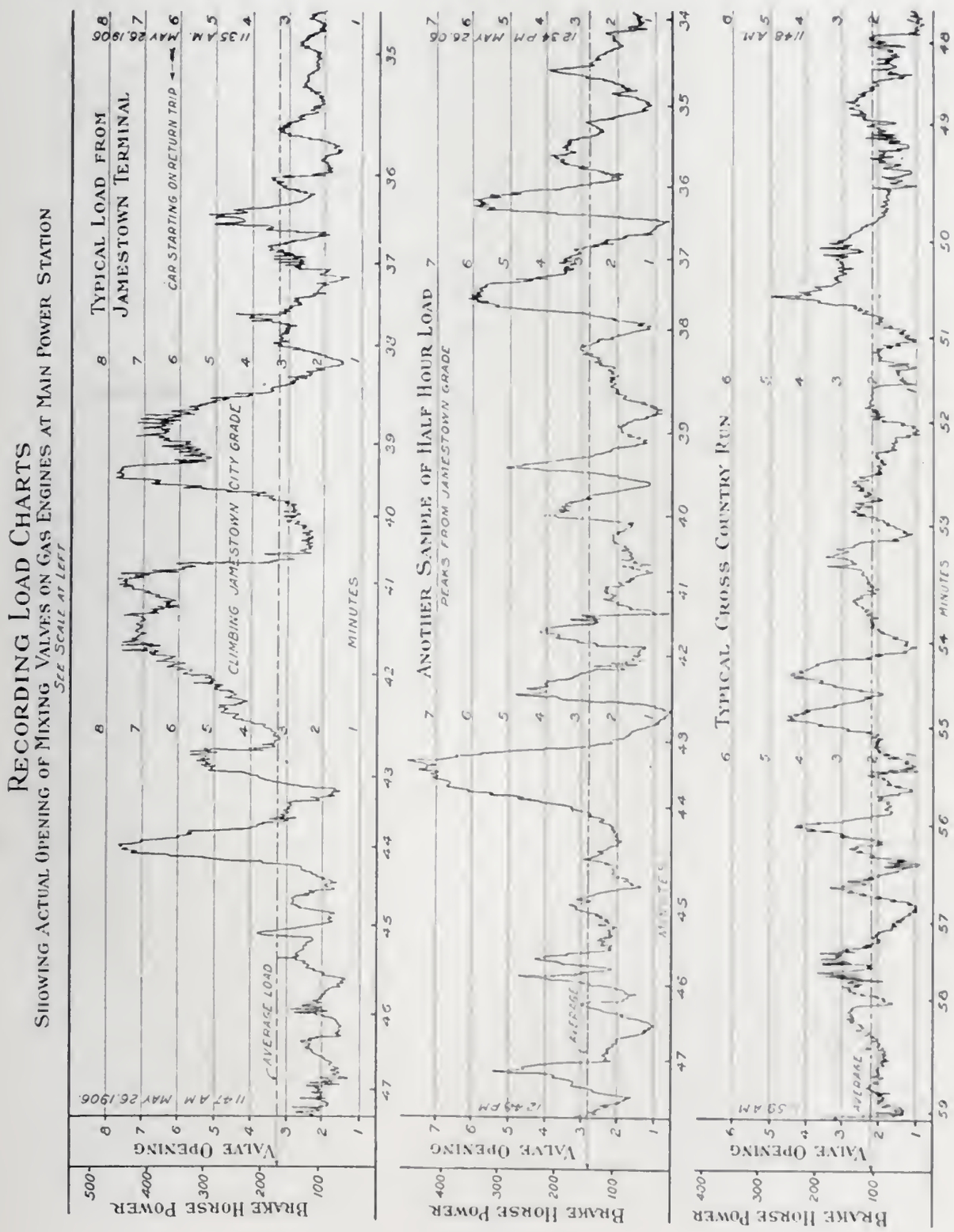


Fig. 1. Typical Record of Engine Load.

ders. Consequently it is proportional to the effective load, and the ordinates record the fluctuations of power which must be met by the generating unit. Incidentially, it shows the sensitiveness which characterizes the method of governing used.

These three samples shown were taken from a long strip of record covering one hour time, each strip corresponding to an interval of about ten minutes during different parts of the hour's run. The upper strip records the load occuring regularly through the day at half after the hour. At this time one interurban car leaves Jamestown on its return trip, and the heavy load at 11:30-11:42 results from the long grade leading out of the city. About this same time another car is running across country, as shown by the train sheet (Fig. 2), while a third car is just pulling into the Warren terminal. The second strip records a similar load one hour later and shows practically the same characteristics. On the third strip is recorded the comparatively easy load which results from two cars out on the line.

The scale for these records, affixed at the left hand margin, was constructed by making a few observations at the end of the run at several different points of valve opening corresponding to various loads coming within the range of fluctuations. This method was found to be quite accurate, checking closely with observations made at intervals during the time the record was being taken.

Observe now that within these ten minute intervals there result from 15 to 18 peaks with load varying from less than 100 horse power up to the rated capacity of the engines, or 335% fluctuation above mean. Furthermore, note the suddenness with which these loads increase and decrease as shown at 11:44, 12:36, and 12:44 respectively. Previous to May, 1906, when a 90 minute schedule was in use, cars started simultaneously from the two terminals, which still further accentuated the severity of the load fluctuations at the plant. At the present time express cars on their regular daily runs carry loads varying from 3 to 15 tons; it is nothing unusual for these cars

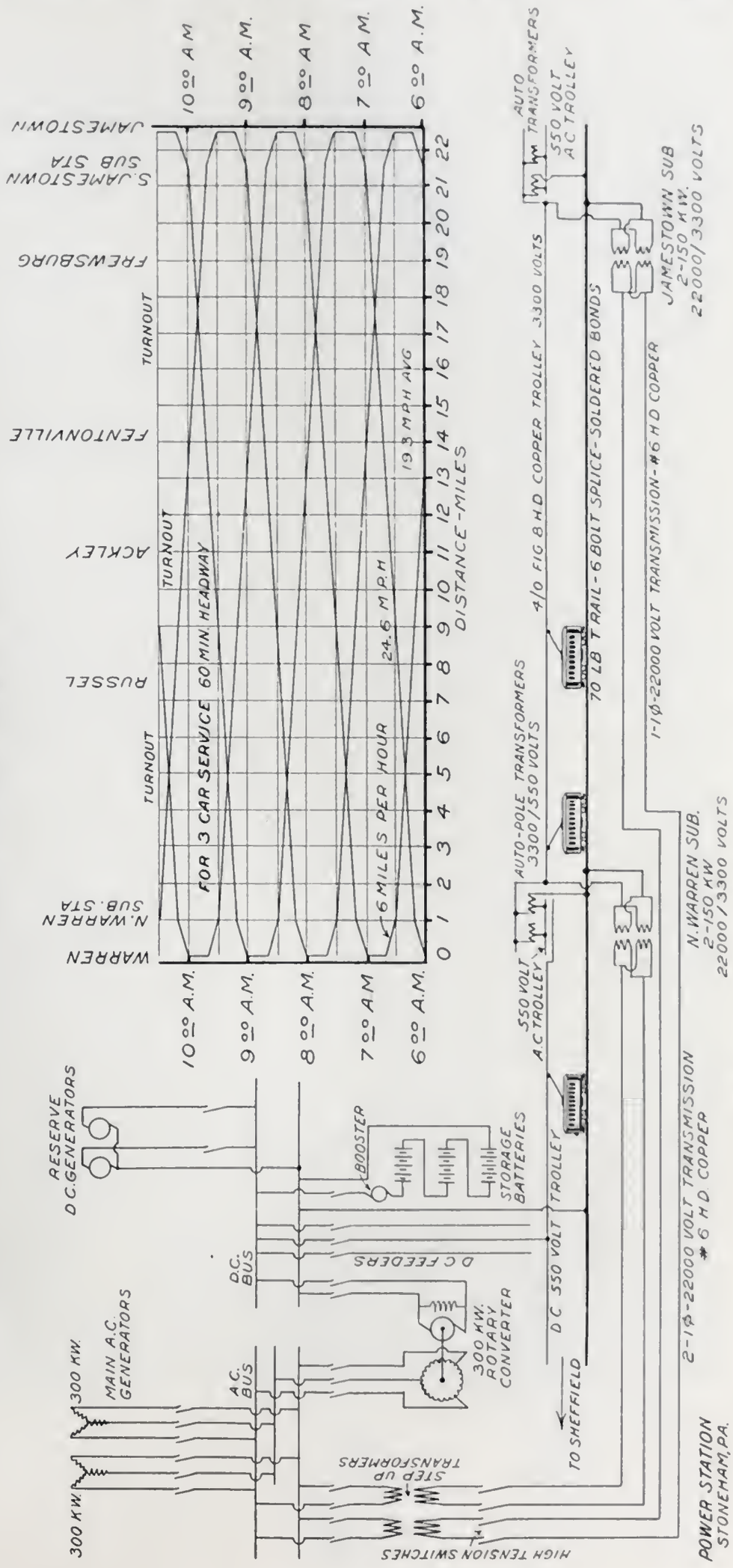


Fig. 2. Train Sheet and Power Distribution System.

to haul 15 barrels of oil, or a load of dressed oak timber, which pulls heavily on the steep grades. It is unnecessary to emphasize the fact that this kind of load is the worst that a reciprocating engine can be called upon to sustain; the fact that the Warren plant is capable of meeting these fluctuations without rapid deterioration should furnish a convincing proof of the stability of the modern gas engine.

Another point of importance bearing upon the success of a power plant is the character of labor available. Owing to the distance of the plant from the city and its complete isolation after running hours, it is difficult to retain skilled operatives. Thus, at the present time, although one such man is retained as superintendent, the remaining attendants were quite inexperienced, most of them having come up from the ranks in street railway service or from outside employment. During the past six months these men have acquired sufficient knowledge and skill to enable one of their number, a comparatively young man, to take entire charge during the night run.

POINTS DEVELOPED FROM OPERATION.

A general survey of the operation of the Warren gas engine plant up to the present time brings to mind the following points that would now seem to have been established:

1. Ability to handle variable loads.
2. Regulation suitable for alternating current parallel operation.
3. Effect of misfires negligible.
4. Sufficient reliability for regular daily service.
5. Deterioration from wear quite normal.
6. General character of labor required not above the ordinary.
7. Oil and water consumption low. Automatic systems desirable.
8. Automatic starting system quite sufficient for any emergency.

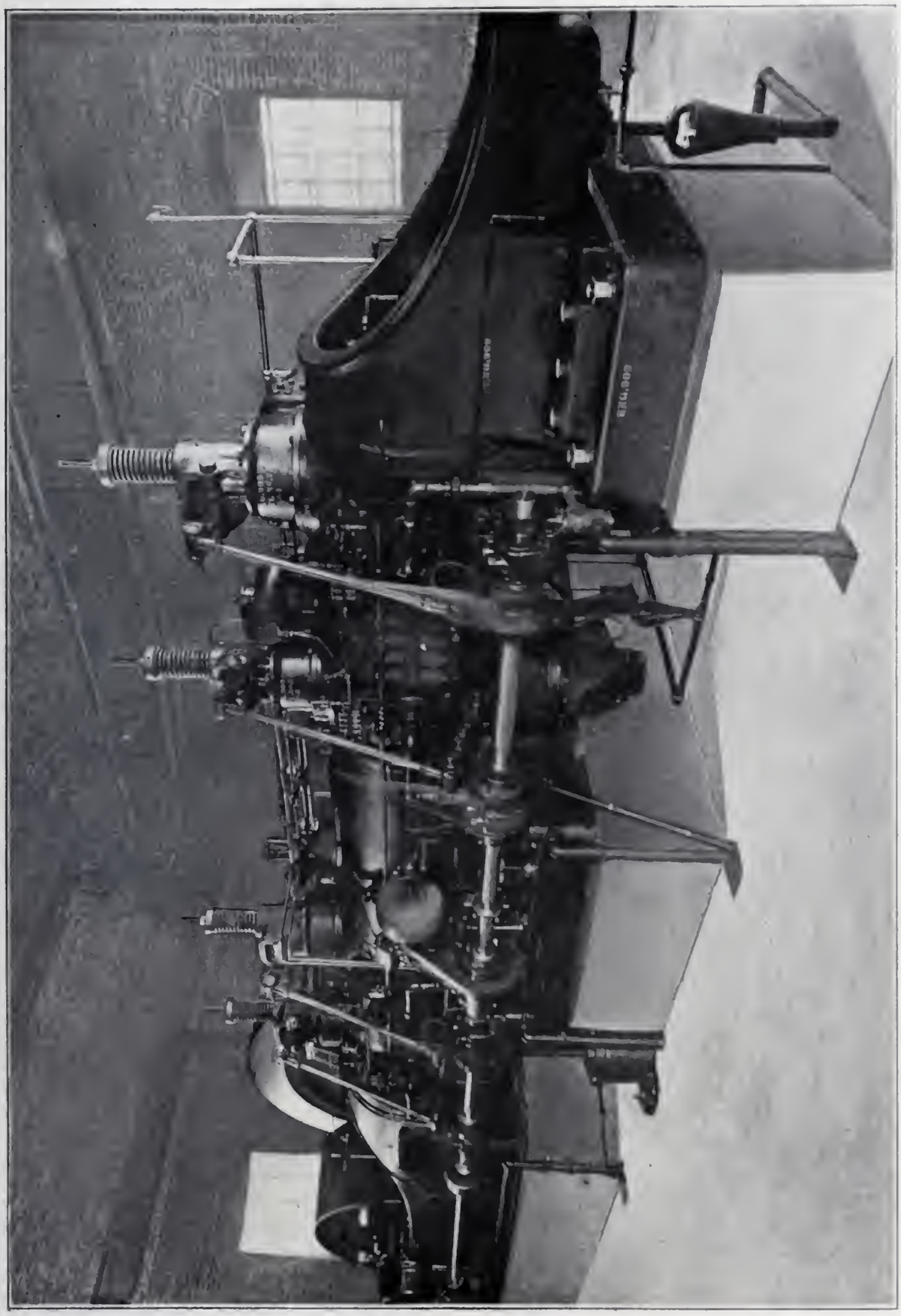


Fig. 3. Side View of Complete 500 H. P. Unit.

Not the least impressive feature of the Warren plant is the ease in which the gas engine units are operated in electrical parallel. They are synchronized by the ordinary lamp method and on opening throttle. The author has observed the entire operation of unloading, synchronizing and loading again accomplished within a period of 25 seconds without the least evidences of surging at the instant of closing of the switches. When synchronizing, loads are distributed in the manner usual with steam machinery, the governor adjustment being accomplished with an adjustable lever arm attached to the regulator by a spring cushioned oil dash pot, shown in Fig. 3. In practice the governors are so adjusted as to give practically the same port opening at the mixing valves, which insures a fairly even distribution of load at the switchboard. During the excessive load fluctuations reproduced in Fig. 1, the units showed no tendency to hunt; in fact, operated with the greatest stability on the heavier loads.

The effect of misfires on parallel operation has been subject to much conjecture and it is of interest to know that, although misfires occur now and then as they are bound to do, in not a single instance have electrical troubles resulted during normal operation. With one cylinder entirely isolated by a defective igniter it is, of course, probable that some surging would result, but the misfires that do occur are so seldom continued and are so easily remedied that no trouble whatever is apprehended from this source.

In the ignition system the well-known electric "hammer break" style of igniter has proven the most serviceable, and with very ordinary care no trouble is experienced in obtaining sufficiently reliable ignition for polyphase working. Originally some annoyance was caused by the sweating of igniter plugs while the engine was starting from cold, but this was readily overcome by venting them to the atmosphere. A complete stoppage from defective ignition is very improbable, for with both storage batteries and dynamo, two combinations of current are available at each combustion chamber. Further, the

igniter circuit to each cylinder is separated into two independent sections, each controlled by individual switches.

As to the general reliability, the facts presented are self-explanatory. After a six weeks run the unit first started was shut down to examine its internal condition. Every part was found to be in good working order without evidence of excessive wear or stress; in fact the cylinders still retained their original tool marks. Since then the engines have been in such constant service that no opportunity has presented

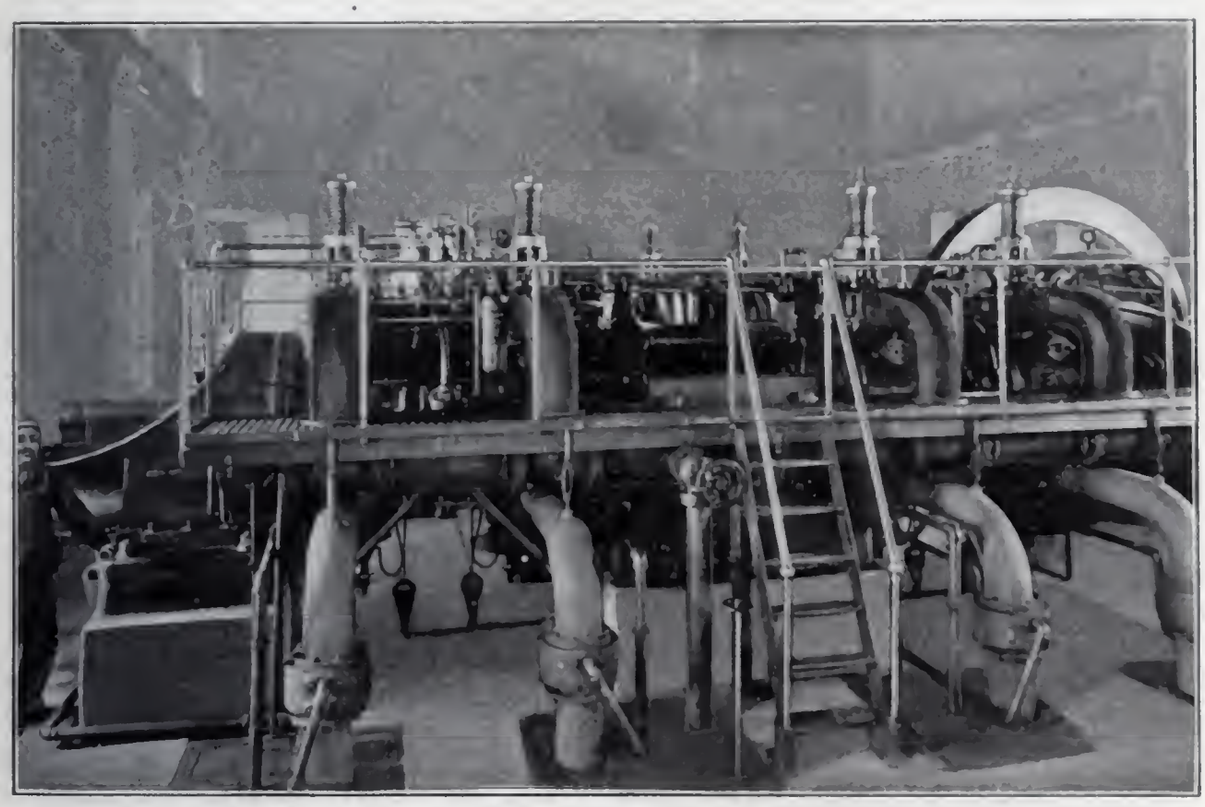


Fig. 4-A. Rear of 500 H. P. unit Exhaust Side, showing Main Throttle and Air Valve in foreground.

itself for further inspection, and all detail parts are operating in their original condition with the exception of the igniters. These are, of course, periodically removed for cleaning during the early morning shut down. It is a significant fact that in spite of the hard service, exhaust, admission and mixing valves, piston rods, glands, connecting rods, main bearings and cylinders have operated without mishap and show no evidences of abnormal deterioration after seven months daily run. The imported Hartung regulators have developed a slight wear

in pins, but this will be corrected by improved lubrication. The one accident occuring during this period was the breaking of a metal cage surrounding the piston rod packing glands, which was caused by excessively thin metal due to the accidental shifting of the sand core in casting. Piston rods have done exceptionally well in regard to wear owing to the efficient packing and method of gland lubrication; both rods have retained their original polish and run quite clean without tendency to gum.

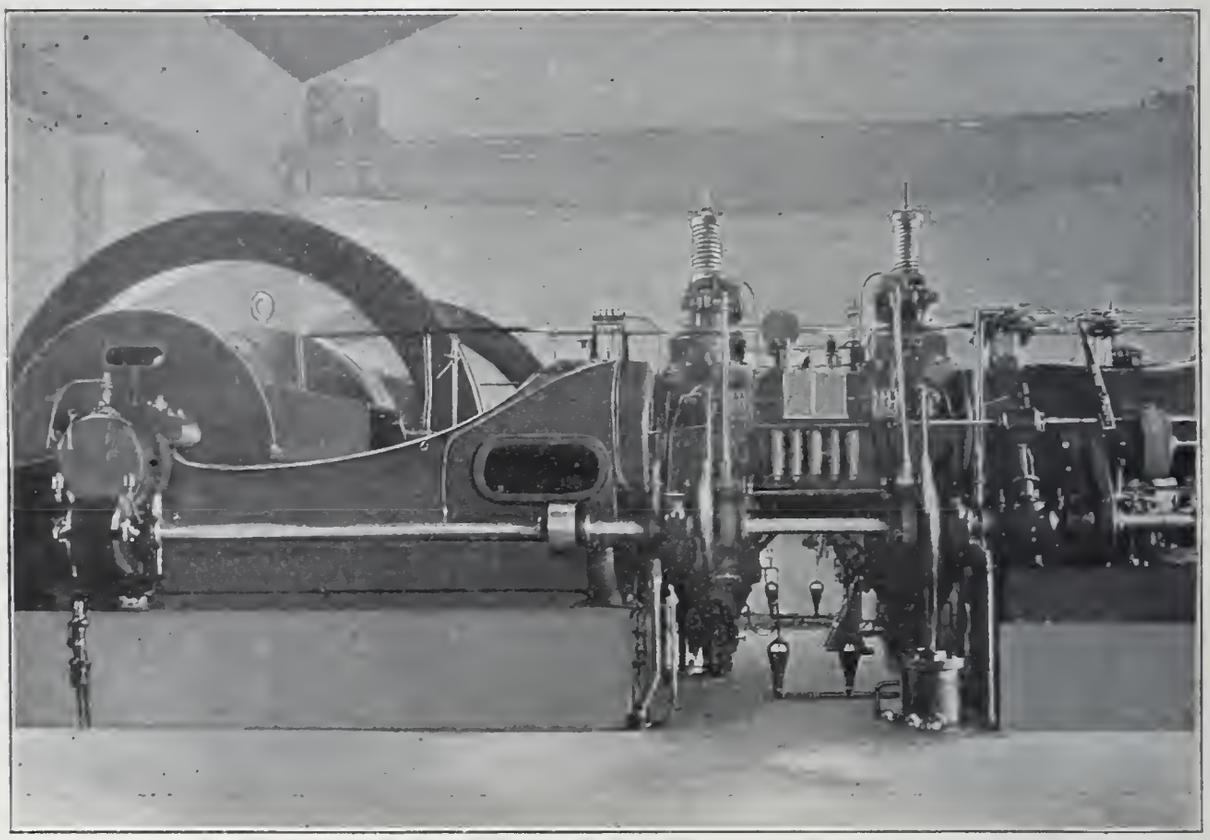


Fig. 4-B. Forward half of 500 H. P. unit, showing Main Frame and Method of Cylinder Support.

Undoubtedly no small part of the success in operation is traceable to the oiling system. Realizing that oil is an absolute essential and that oilers are human beings and, therefore, not infallible, the designer has relieved them of the greater part of their responsibility by using a continuous circulating and filtering system. This also results in a great saving of lubricant, which in turn encourages the use of the highest grade oil. Cylinder lubrication is particularly effective owing to the judicious application of lubricant at just the

right time. The oil is automatically injected into the cylinder at several points, but only on the induction stroke; not promiscuously, as is almost universally done, resulting in the carbonization of by far the largest proportion. By the end of the compression stroke the oil is thoroughly distributed. Table I. gives the oil consumption as charged to the main plant. It is augumented by the fact that more or less oil is drawn out of the system weekly for use in auxiliaries around the plant, this being replaced by fresh oil. Some cylinder oil is also saved from piston rod glands, as all drainage is caught, mixed with old engine oil, and utilized in crank cases of the exciter engines for which no oils are regularly purchased. This accounts in part for the quantity of cylinder oil used, which is somewhat higher than in other engines of the same size and design, a gallon per engine per day being sufficient in most cases, with clean gas.

Table I.

OIL CONSUMPTION.

4 months ending Sunday, May 23, 1906.

	CYLINDER OIL°	ENGINE OIL*
Kind	Imperial Cylinder Oil	Special Gas Engine Oil
Maker	Union Petroleum Co., Philadelphia	
Price (barrel lots)	32c per Gal	18c per Gal.
Quantity used	561 Gals.	765 Gals.
" " per month	140¼ Gals.	191¼ Gals.
" " " (opertg.) day	4.68 Gals.	6.38 Gals.
" " " Full "	6.07 Gals.	8.27 Gals.
Engine Hours per day	37	37
" H.P. " "	18500	18500
Oil per Engine Hour	0.127 Gals.	0.172 Gals.
" " H.P. "	0.000253 Gals.	0.000345 Gals.
Cost per Engine Hour	4.05c	3.1c
" " H.P. "	0.00809	0.00621
Total Cost	0.0143c per H.P. Hour	

°Note—Includes crank case oil for exciter engines. Drainage from glands of main engines collected, mixed with old engine oil and used in crank case. No crank case oil purchased.

*Note—Includes oil consumption of auxiliaries. Sufficient quantity old engine oil drawn from circulating system to supply auxiliaries replaced by fresh oil.

Water consumption, however, is rather low, due to the fact that the average load on the engines is considerably below rating and peaks are of short duration. Owing to the abundant supply available the jackets are run unusually cool. (See Table II.) It is noteworthy that successful circulation is being obtained from the elevated tank without the use of a pressure pump to supply pistons. At Warren the extraordinary purity of the water makes clogging of water ducts improbable and 10 lbs. hydrostatic head may therefore be depended upon with entire safety.

Table II.

WATER CONSUMPTION—MAIN ENGINES.

Source—Spring water, no suspended matter.
Storage System—Cistern, auto-raising pump, elevated supply tank.
Pressure at Engines Average—9 to 10 pounds per square inch.
Quantity used per hour per engine—2824.5 gallons.
Water per B. H. P. per hour, full load—5.65 gallons.

TEMPERATURE APRIL 27, 1906, 39° F.		RISE.
INLET	39° F.	
Tail Rod (rear)	102	63° F.
" " (front)	98	59
Cylinder Jacket (rear)	108	69
" " (front)	104	65
Cylinder Head (rear)	102	63
" " (front)	104	65
Exhaust Valve (rear)	68 and 61	29–22
" " (front)	64 and 66	25–27
OUTLET AVERAGE	93°	54°

The automatic compressed air starting mechanism has proven to be one of the most effective details of design and has never failed, providing the proper pressure is maintained in the tanks and the ignition is in good working order. In starting the engines, only two valves are manipulated, viz. compressed air valve and the gas valve, both shown in the foreground (Fig. 4A), and usually the engine "catches" its ignition in two or three strokes, coming rapidly up to speed within one minute.

OPERATING DATA.

In the accompanying tables it has been attempted to summarize the most important operating data pertaining to the power equipment of the system for a period covering normal operation under different conditions. Previous to December the interurban road was not in complete shape and operating data therefrom would not be representative. The car mile and ton mile has been taken as a basis for all computations, Table IV. giving the fundamental data for arriving at these quantities. Table III. shows the average fuel gas consumption for the interurban system alone, and for the interurban and city system combined. A fuel gas bill of $10.00 to $12.00 a day for 42 miles of road clearly indicates the economy of gas power, especially with the price of gas equivalent to $4.00 coal.

Table III.

FUEL GAS CONSUMPTION.

MONTH	CUBIC FEET		COST—$		REMARKS
	Month	Day	Month	Day	
1. Dec.	1,701,000	54,870	255.15	8.23	Interurban System only, 2 Cars
2. Jan.	2,753,000	88,806	412.95	13.32	Inter & City System, 10 Cars
3. Feb.	2,360,000	84,285	354.00	12.64	" " " "
4. March	2,546,000	82,129	381.90	12.32	" " " "
5. April	1,727,000	57,566	259.05	8.63	Mostly Interurban, 2 Cars
6. May	2,633,000	84,935	394.95	12.74	Entire System, 11 Cars
Average	2,286,667	75,432	343.00	11.31	
Avg. (2, 3, 4)	2,553,000	85,073	382.95	12.76	Combined System
Avg. (1 & 5)	1,714,000	56,218	257.10	8.43	Interurban System

*Including all gas for heating power house during cold weather.
Gas from "Bradford Sand," Elk County, 1000 B.T.U. per cu. ft. (approx.)
Price—15c per million B.T.U.=1c per 66,667 B.T.U.
Equivalent cost of coal (13,500 B.T.U. per lb.)

$1.00 Ton= 3.7c per million B.T.U.
2.00 " = 7.41c " " "
4.00 " =14.82c " " "
15c per million=$4.05 per ton coal.

Table IV.

SUMMARY OF OPERATING COST DATA.

SYSTEM	A. C. Interurban System Only		A. C. Interurban & D. C. Urban		A. C. Interurban & D. C. Urban	
MONTH 1905-6	Dec. & April		Jan., Feb., Mch.		May†	
Interurban Schedule*	1½ Hours		1½ Hours		1 Hour	
Number of Cars in all, Regular Service	2 Passenger 1 Express		2 Passenger 1 Express		3 Passengers 1 Express	
Weight of Cars	35 Tons		35 Tons		35 Tons	
Headway	90 Minutes		90 Minutes		60 Minntes	
Lay Over	50 Minutes		50 Minutes		20 Minutes	
Operating Time	17½ Hours		17½ Hours		18½ Hours	
Total Number Round Trips	14		14		20	
Total Mileage per Car	315		440		440	
Car Miles per Day—Interurban	630		630		880	
" " City	.....		2381		2381	
Total Car Miles	630		3011		3261	
Ton Miles per Day—Interurban	22050		22050		30800	
" " City	.....		27310		27310	
Total Ton Miles	22050		49360		58110	
Average Tonnage per Day	35		16.4		17.82	
	Month	Day	Month	Day	Month	Day
Cost Fuel Gas	$257 10	$8 43	$382 90	$12.76	$394 95	$12 74
Wages	296 00	9 79	371 00	12 37	371 00	12 37
Oil	80 00	2 65	80 00	2 63	80 00	2 63
Sundry Supplies and Repairs	100 00	3 31	100 00	3 29	100 00	3 29
	$733 10	$24 18	$933 90	31 05	$945 95	$31 03
Total Cost per Operating Hour	$1.38		$1.774		$1.677	
" " 24 Hours	1.01		1.295		1.294	
" " Car Operating Hour	0.645		0.194		0.166	
" " Average Car Mile	3.84c		1.031c		0.95c	
" " Average Ton Mile	0.1096c		0.0629		0.0534	
GAS CONSUMPTION per	Cu. Ft.	Cost	Cu. Ft.	Cost	Cu. Ft.	Cost
Average Car per Hour	1503	22.5c	532	8.04c	454	6.81c
" Car Mile	89.3	1.34	28.3	0.427	26	0.391
" Ton Mile	2.55	0.0383	1.72	0.0261	1.46	0.022

†May expenses (except gas) averaged on 30 day basis.
*Warren City System.

	Sheffield.	N. Warren.	City.	Total or Avg.
Length of Line (miles)	11	3	7	
No. Cars in regular operation	2	1	4	7
Headway, Minutes	60	20	15	
Weight of Cars (Avg. Tons)	18	15	10	11.5
Operating Hours per Day	17	17	17	17
Car Miles per Day	374	102	1905	2381
Ton " " "	6730	1530	19050	27310

In Table IV. the total operating costs, on a basis of car and ton mile, are summarized for three definite operating conditions. As the one hour schedule has been in force only about one month, the costs for May may not be quite as representative as those covering 1½ hour headway. Further, the costs for December and April are if anything high for the reason that during April the interurban plant furnished some power to the urban system during some work on the electrical machinery, although the results are considered as applicable to the interurban system only. In order to render the results from May more comparable with those of shorter months, the costs (except gas) are figured on a basis of 30 days.

Comparing these costs, the fact appears that the entire 42 miles of railway is now being operated for about $31.00 per day, or $1.67 per operating hour. The interurban system, running alone, averaged a little under .11c per ton mile, or 3.8c per car mile total operating costs. With the city system serving to increase the load factor on the plant the total operating cost per ton mile was reduced to .05c, practically half, and the cost per car mile to less than 1c. Comparing these costs with those of independent operation of alternating current and direct current plants respectively, a net saving in fuel of approximately 20% has been realized. It is interesting to note the interurban cars alone required 89 cu. ft. of gas per car mile, or 2½ cu. ft. per ton mile; at present the average gas consumption is 26 cu. ft. per car mile and 1½ cu. ft. per ton mile. Further, note that the effect of shortening the schedule with a third interurban car is barely noticeable on the expense sheet, but it occasions a considerable reduction in mileage costs—from 10 to 15%. These figures, although

not as accurate and comprehensive as could be desired, yet are significant of the general all around commercial efficiency of the system as installed.

In conclusion, a review of the results achieved at Warren cannot help but impress one with the fact that numerous predictions of failure of gas power in railway service are not based upon experience with modern high grade equipment, and the author will consider himself fully repaid for the work of preparing this paper if he shall have succeeded in bringing home to you this one fact. The most casual reader of technical literature cannot help but be impressed with the extent of the gas power work going on abroad, and it is high time that power users were brought to a realization of the resourcefulness of American engineers. The city of Johannesburg, South Africa, is installing an 8,000 kilowatt producer gas engine station which will operate the entire light, power and traction system of the city. A similar equipment is nearing completion at Madrid, Spain. In view of recent American engineering progress the reasons are not apparent why this country should not at least follow the lead, if not set the pace.

APPENDIX.

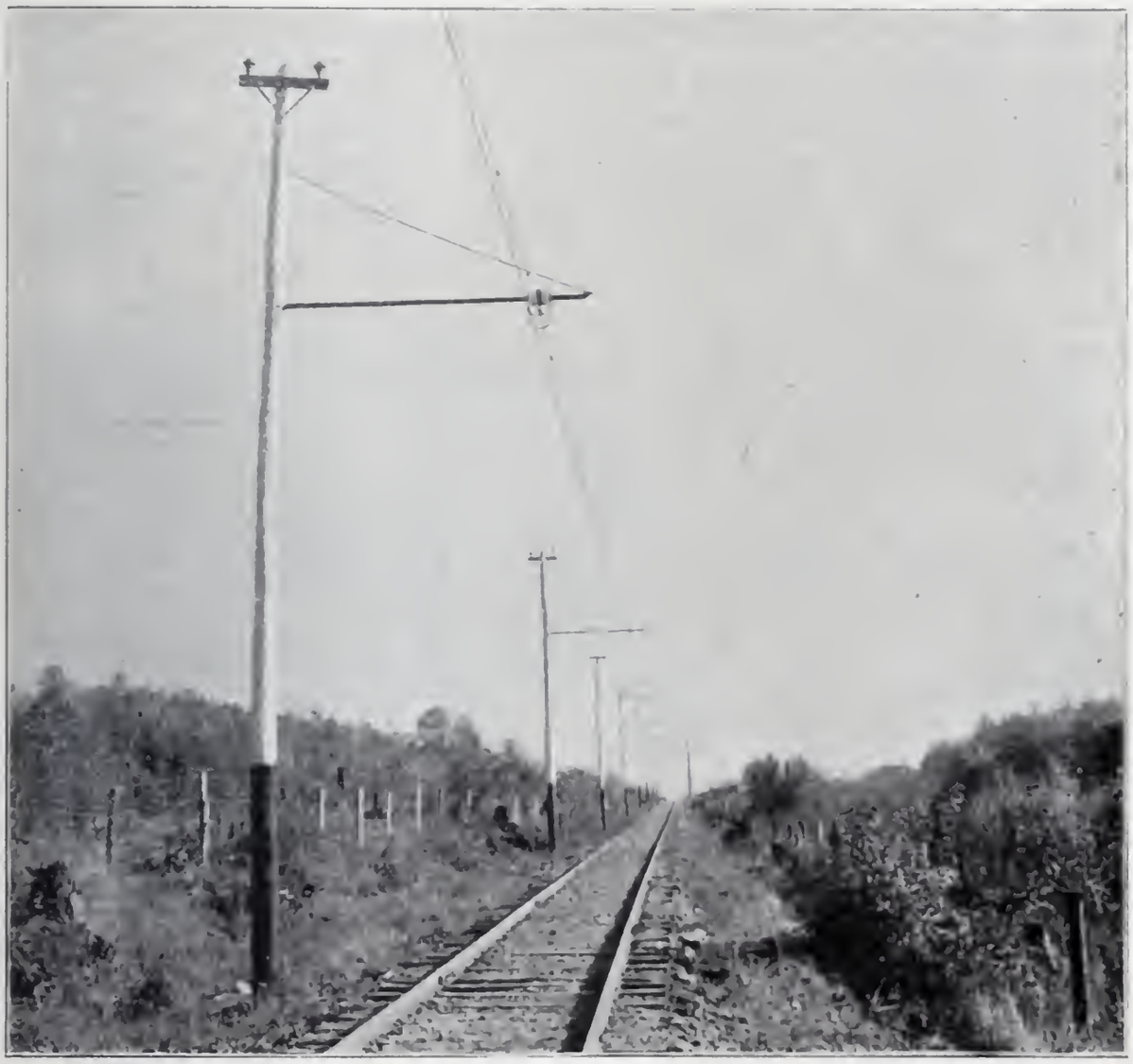
DESCRIPTIVE.

Route and Traffic.

Operating between two of the largest towns in the vicinity of Warren, Pa., and Jamestown, N. Y., the interurban road (Fig. 7) traverses a territory well populated and exceptionally well situated to develop an extensive freight business. The right of way, 22.5 miles in length between terminals, passes through 9 towns, totaling 50,000 population; 9 contiguous towns with a population of 11,900 bring the total tributary population up to 61,500, exclusive of summer residents. As Lake Chautauqua and vicinity is a popular summer resort the maximum tributary population is estimated close to 100,000 people. No direct competition exists, there being only a branch

connection at Jamestown by trolley from the Dunkirk, Allegheny Valley & Pittsburg R. R.

Light freight traffic is becoming an increasing factor in the operation of the line as the electric road offers by far the greatest facility for rapid and cheap transportation of garden,

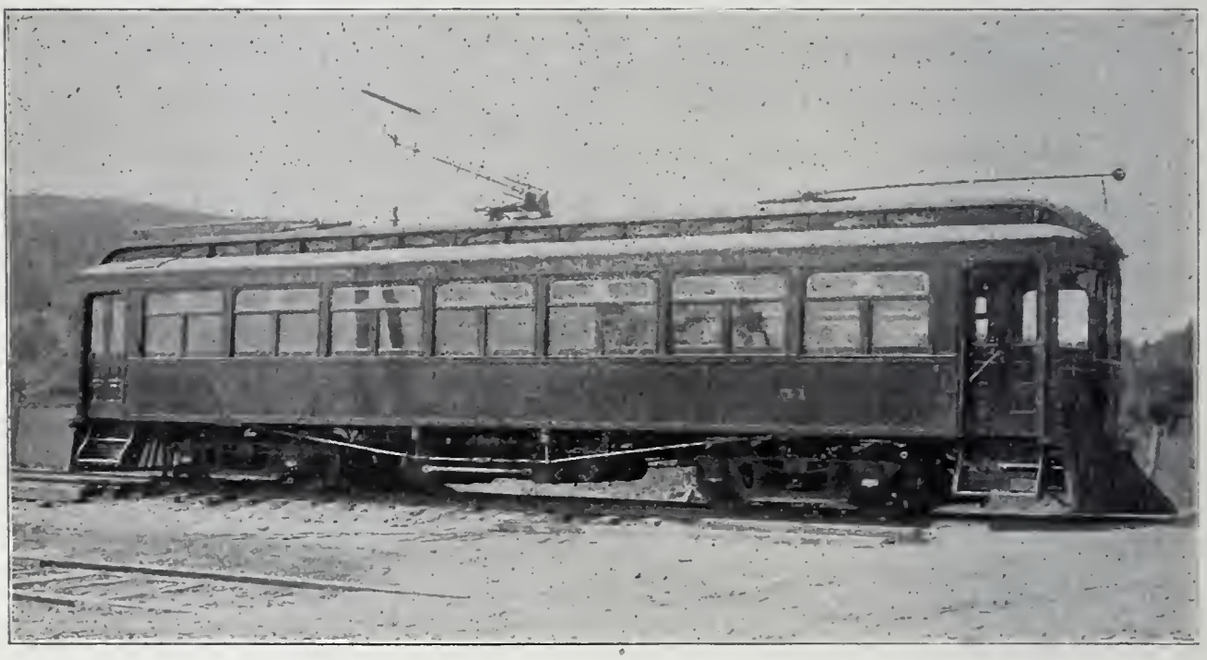


Typical view along right-ofway showing overhead construction on a tangent.

dairy and manufactured products from the smaller farms. As an example of the possibilities in this line, a single express car now in service, making four trips per day, handles on an average 3 tons of express matter per trip, the hauls sometimes amounting to 10 tons or more.

Permanent Way.

In general the road bed is of good construction, fairly direct, and with the exception of some unavoidable grades, rather level, but to accommodate the peculiar contour of the country a large number of curves had to be run in. One of the grades is particularly difficult, being nearly three-quarters of a mile in length with an average rise of 3½% and a maximum rise of 7%; an unavoidable stop just at the foot of this grade makes it difficult to climb. A long heavy grade also occurs in the city of Jamestown. The track is constructed with 70-pound rails, gravel ballast, spring frogs, and rail elevation on curves to accommodate a speed as high as 50 miles per hour.



Standard Passenger Car. Note two trolley systems, the bow for high tension and the ordinary trolley for low tension.

Rolling Stock.

All of the interurban rolling stock is of unusually substantial construction, cars being 52 feet in length over all, and weighing about 35 tons equipped. Passenger cars have a seating capacity of 59 people; express cars are practically of the same size, all having a motor equipment of four 50 horse power Westinghouse single phase series motors connected in multiple, with duplicate drum controllers. These cars make

a daily schedule of about 20 miles per hour, with stops averaging 2½ miles; there are 55 regular stations along the line, the average run including about 15 stops. On through runs without stops an average speed of 30 miles an hour is usually maintained, while maximum speeds range up to 50 miles an hour. The cars have 33 in. wheels with 5½ in. axles and Brill trucks, and are exceptionally handsome in both interior and exterior finish.

Warren City System.

In connection with the interurban line between Warren and Jamestown, the entire city system at Warren is operated from the main power house at Stoneham. Approximately 20 miles of single track line is in service with seven 2 motor single truck cars, weighing about 10 tons equipped. On two of the longest branches double truck cars are used with 2 and 4 motor equipments. Current formerly supplied from the old gas engine units at the power house is now supplied from the new alternating current generating plant through rotary converters. A storage battery is ordinarily operated in connection with the direct current plant.

Power Distribution System.

Power for the entire road is transmitted at 22,000 volts from the power house at Stoneham by overhead line to two 300 kilowatt transformer stations located about one mile from the respective terminals. These transmission lines are duplicated for greater safety. At the transformer stations the current is reduced to 3,300 volts for delivery to the overhead trolley, from which it is collected by bow trolleys on the cars held in contact position by compressed air. This trolley construction is a feature of the line, being of the catenary suspension type with insulated steel messenger cable from which the "8" trolley is suspended.

The high tension trolley is continuous, one end being fed from the Warren sub-station, the other from the Jamestown sub-station. With two independent transmission lines running from the power house to these two sub-stations it thus

occurs that the two sections of the line are mutually independent, except in their effect on the generating plant.

Within the city limits of Warren, where high voltage is not permissible, ordinary 500 volt span wire trolley construction is employed paralleling the direct current trolley at a distance of about 8 in. Current at 550 volts is supplied by pole transformers of the auto type reducing from 3,300 volts.

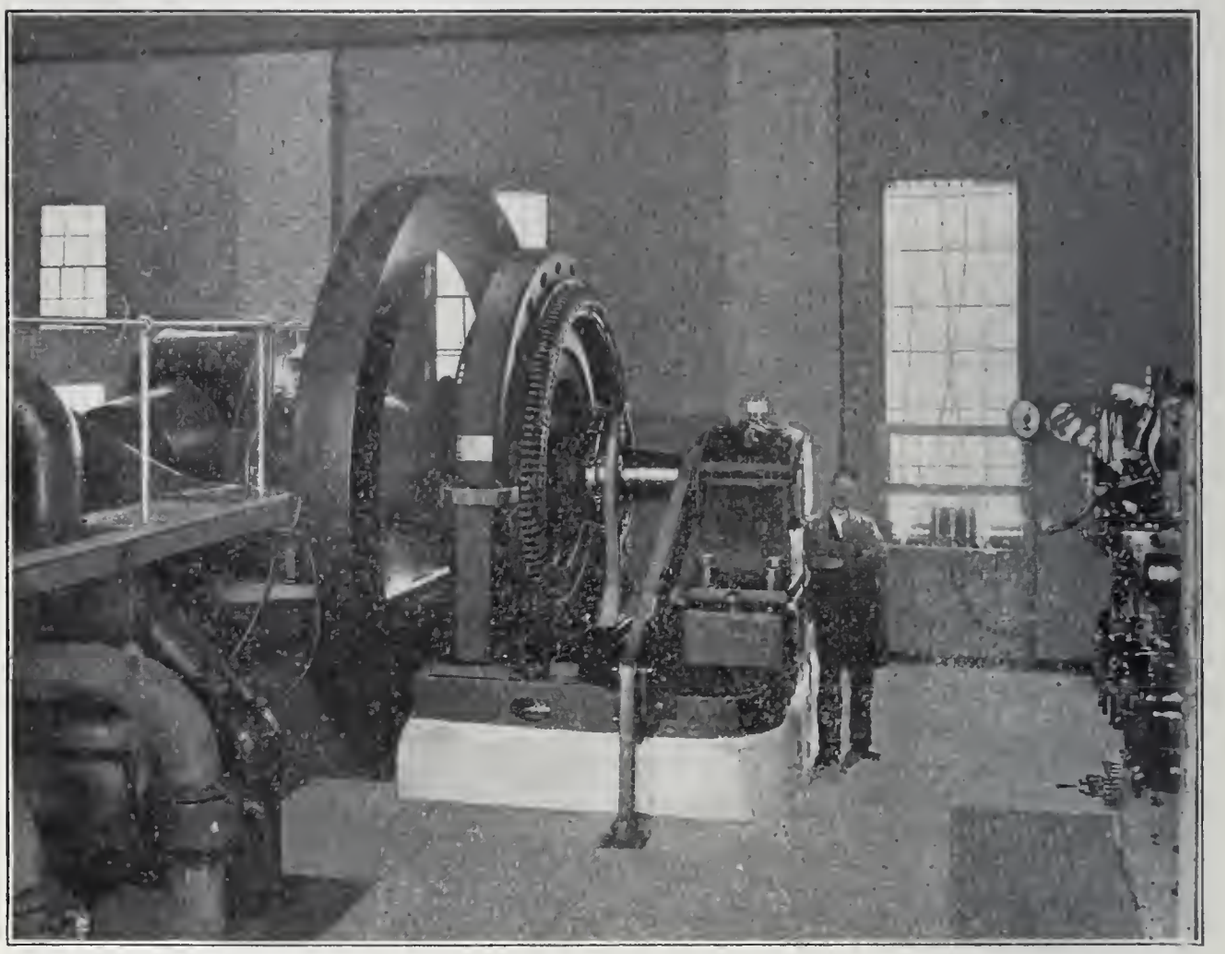


Fig. 5. Generator End of Main Gas Engine Unit. Auto Stop at Flywheel Rim.

A multi-voltage transformer on each car reduces the normal line pressure to a maximum of 550 volts at the motors, various lower voltages being used for different running speeds. The controllers provide for five speeds, each of which is a running speed, and give unusually uniform acceleration. In case of accident to the bow trolley either of two wheel trolleys may be used as they are insulated for this purpose and may be connected to the high tension circuit by an oil switch.

Power Station.

By reference to the map (Fig. 7) it will be noted that the power station located at Stoneham is by no means near the electrical center of gravity of the distribution system. It was thought undesirable to abandon the old station at Stoneham as important extensions in a southerly direction were possible. Furthermore, four gas pipe lines pass this point, any one of which may be tapped for fuel gas.

The alternating current generating equipment consists of two 300 kilowatt engine type units installed in an extension to the old plant which is now maintained only as an emergency

Standard Baggage Car.

reserve for the direct current system. These two main units generate current at 360 volts serving the interurban system single phase and the urban system three phase, the latter through a 300 kilowatt rotary converter. Thus the loads from the two systems are superposed and, unfortunately, the peaks of the one occur at nearly the same time as the other. The generators (Fig. 5) are standard three-phase machines of the revolving field type mounted solidly on the engine shafts. They are controlled by a standard switchboard in precisely the same manner as steam units. Excitation is furnished by two small

gas engine units of the belted type (Fig. 6), one being held in reserve. One of these exciter engines drives a small two-stage air compressor for supplying the air starting system and a small igniter generator.

Air storage tanks are installed in the basement and are always maintained full of air up to 240 pounds pressure. Piping to the several tanks is arranged in such a manner that in starting the engines only one or two tanks need be drawn upon, the others being shut off by a valve, so that maximum

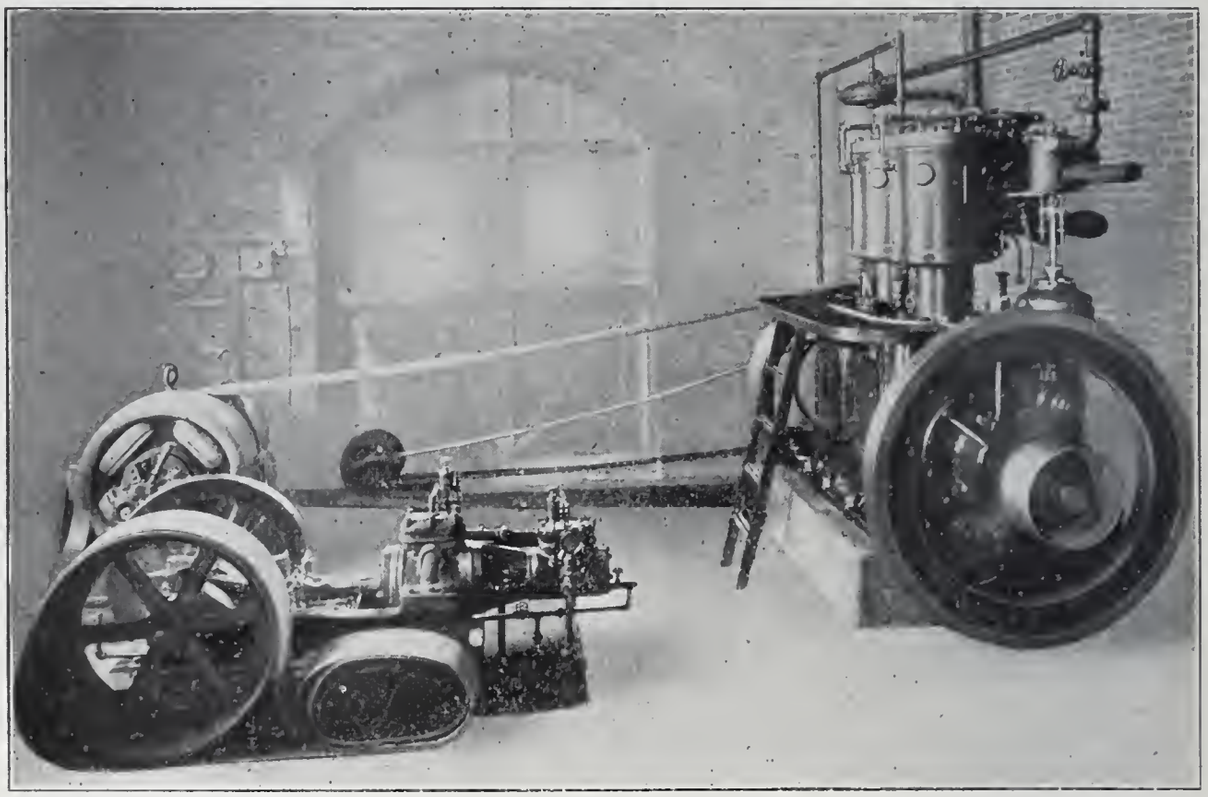


Fig. 6. Auxiliary Plant, showing arrangement of Exciter, Compressor, and Igniter Generator.

pressure is at all times available in case of necessity long before the compressor could have refilled the exhausted tanks.

Fuel gas is delivered at about 125 pounds pressure from the main line of the Warren & Chautauqua Gas Co. This line is supplied by 32 wells in Elk County, all issuing from the "Bradford Sand" strata. Gas is delivered to the engines at atmospheric pressure through two regulators in series at the meter house, a large boiler steel tank plant in the supply house main serving to absorb vibration due to engine suction.

Important Features of Gas Engine Design.

By reason of this tandem arrangement of cylinders each engine gives a power impulse at each forward and backward stroke precisely as in a double acting steam engine. In fact the general design is characterized by strong adherence to established steam engine practice. The indicator cards (Fig. 8) shows in a measure this resemblance.

Perhaps the first impression is gained from the cylinder

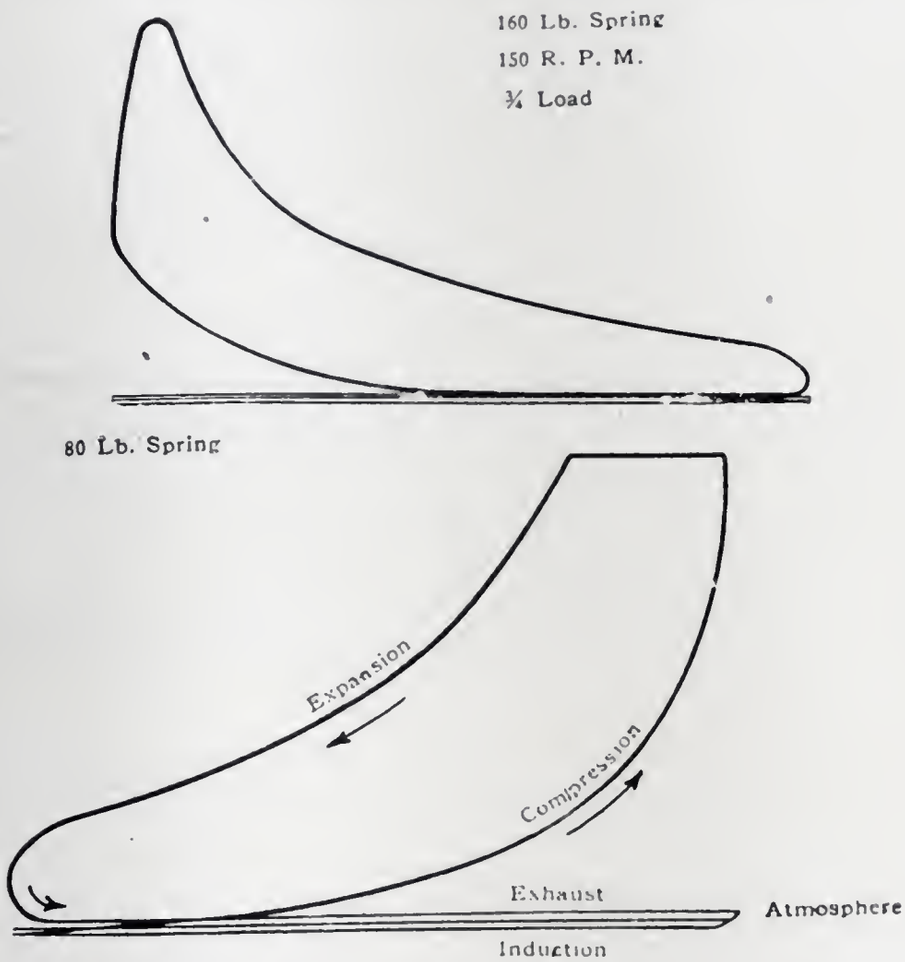


Fig. 8 Indicator Cards from 500 H. P. Engine at about three-fourths Load.

arrangement (Fig. 4-B). Owing to the floating of pistons entirely free from the cylinder body, the cylinders are not supported directly from the foundation, instead the forward, center and rear housing rest upon concrete piers rising about two feet above the floor line. The cylinders are then supported by recessed flanges in each opposing face of the housings, and being of strictly symmetrical design the cylinder body is quite free to adjust its fibre stresses. Each cylinder may thus be consid-

ered as a beam, but with static loading only, as the entire live load is concentrated on the three rod supports which are, of course, best adapted to receive them without periodical deflection. The engine is anchored at the forward housing, but is quite free to expand and contract longitudinally on the sole plates of center and rear housings.

You will observe that the admission and exhaust valves (Fig. 4-A) are mounted in a vertical line at the two cylinder ends, an arrangement providing not only a symmetrical structure but also great facility for reaching the interior; and this consideration for accessibility has resulted in elevating the engine above the floor sufficiently to enable attendants to work at the exhaust valve mechanism from the floor level. All valves are of steel and of the simple poppet or mushroom type.

Owing to the length of the piston rod, and the greater convenience of handling pistons separately, the rod is made in two parts united at the center crosshead. The front piston may thus be removed from the forward end and the rear piston from the rear end. In conformity with this scheme the piston cooling water is also divided; entering at the center crosshead, one half is sent through a bored duct to the forward piston, and the remainder to the rear, thus insuring an even distribution of flow.

A valuable check on internal working is furnished by open funnels inserted in the various cooling water passage outlets arranged at convenient points. By these the engineer is enabled to instantly observe the continuity, temperature and purity of the various cooling water circuits, *e. g.* tail rod outlet (Fig. 3).

The automatic systems for cylinder and engine oil and circulating water supply have already been mentioned; both are extremely important. In regard to detail parts, the valve and governor mechanism embody the most characteristic design. As the maximum terminal pressure is seldom less than 30 pounds per square inch, the pressure required to "crack" an 8 in. or 10 in. valve is nearly a ton, which in turn places great stresses on the exhaust valve mechanism. To relieve

this high pressure at the opening of the exhaust, a multiplying lever motion is used which accomplishes the desirable results shown in Fig. 9, *i. e.* maximum pressure is exerted at the opening of the valves followed by maximum velocity of opening (Fig. 10). This greatly reduces the fluctuating torsion of the lay shaft.

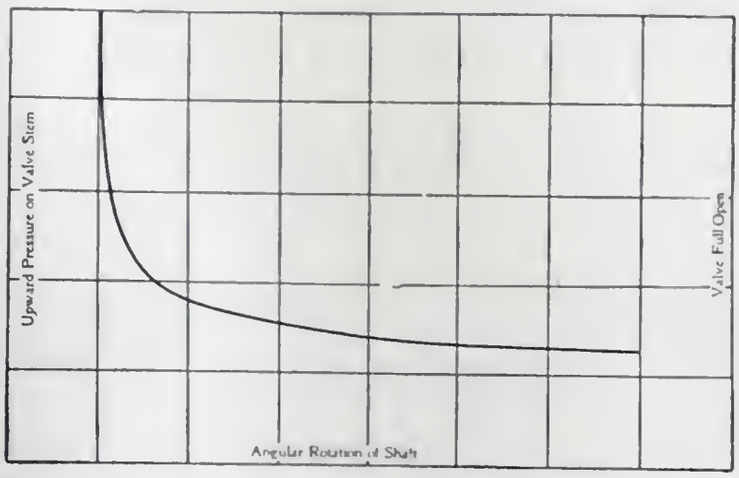


Fig. 9. Pressure Diagram from Exhaust Valve.

Mixing and admission valves have fortunately been combined in a single mechanism quite uncomplicated and requiring practically no attention. Moreover, the control of mixture takes place right at the cylinder, which is, of course, conducive to close governing. The engine operates upon the

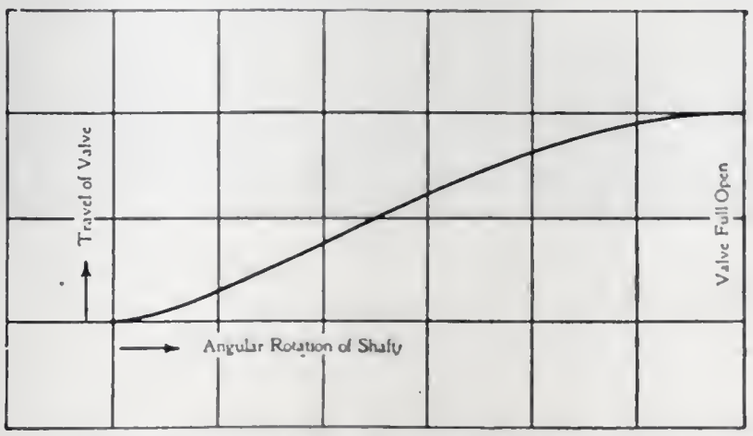


Fig. 10. Velocity Diagram from Exhaust Valve Gear.

familiar four-stroke cycle and the valve is subject to a compound motion, rotary for proper proportioning of gas and air, and longitudinal for admission of a definite quantity at each induction stroke according to the load. Angular rotation controls the relative port opening, while vertical motion admits

mixture to the cylinder. Only the mixing valves are under control of the governor and the position of the several valves are at all times shown by a graduated dial which gives the attendant a valuable hint in properly proportioning the load on his engines.

The governor mechanism is unique in the application of a definite principle, viz. that an engine regulator should not be burdened with the load of moving large masses of metal sub-

Transformer Station. One of the two sub-stations containing all the transforming and protective apparatus for the entire line. No regular attendants necessary.

ject to more or less friction of an uncertain nature. Thus the relay system has been adopted. A small oil cylinder operating under 50 to 60 pounds oil pressure does all the actual work of moving the mixing valves, which the governor proper, which is simply a sensitive centrifugal type regulator, is only called upon to actuate a small pilot which in turn controls the main oil cylinder. Valve sticking thus becomes an impossibility.

The advantages of this system are obvious and have long been in use in steam turbines of the Parsons type. The regulator shown in Fig. 3 is of imported Hartung construction and is geared to the lay shaft through a spring cushion drive for the purpose of absorbing torque variations in the latter. The adjustable synchronizing mechanism previously mentioned affords a delicate adjustment of engine speed for parallel working. On another engine of the same size and construction, and with load fluctuating 80% above and below mean, the engine speed has been held to within four revolutions, or 1⅓% above and below mean speed. For preventing over speed an automatic safety stop of simple design is mounted close to the engine flywheel as shown in Fig. 6. At a predetermined speed the mechanism trips and automatically opens the igniter circuits to all cylinders. This may also be accomplished by hand in case of emergency from either end of the engine.

Two sets of storage batteries are in use to facilitate charging; they serve the igniters alternately and are charged from the exciter bus. For increased safety the igniter board is divided into four independent cabinets, two to an engine. One cabinet controls igniters 1 and 3, the other 2 and 4, etc. In this manner a complete loss of ignition current is improbable, especially with dynamo in service.

DISCUSSION.

K. A. Muellenhoff, Member—One of the chief obstacles to the use of gas engines for this kind of service is the difficulty of caring for the overload. The writer says that "occasionally the peaks go as high as the entire capacity of the plant. Will you not reach a point soon where there will occur occasional overloads; how will you meet that?

Another question is the temperature of the jacket water? Also, how long is it necessary to run the engine with compressed air before ignition takes place, and when can you throw on the load?

J. R. Bibbins—As to overload capacity, the only remedy is to install more machinery. A well regulated plant should

always have one generating unit in reserve. Gas engine overload capacity is now recognized as simply the percentage of maximum capacity by which the builder under-rates his engine. If the purchaser appreciates this point, there is no occasion for misunderstanding. The Westinghouse Machine Company normally rates engines of this large size at about 10% under maximum load, *i. e.* with 10% overload capacity. That rating is deliberately conservative so as to be absolutely safe. In the diagrams shown (Fig. 1) you will notice that on fluctuations the valves have opened to the eighth point. There is still one more point, *i. e.* one-eighth more of the full valve opening to enable us to carry still heavier loads. Of course beyond this maximum point the plant would simply "lie down."

As to the cooling water temperature, the water at Warren is extremely cold and pure. It enters at an average temperature of 39° F., distributing as shown in Table II., and emerges at a temperature of about 100° F. In this particular plant, as there is more water than needed, there is no occasion for economizing in this direction.

The third point was starting. The lay shaft running along the engine is provided with cams at each cylinder end. These cams engage little compressed air valves so constructed that when the air pressure is off, the plungers are down and do not engage the cams; but as soon as the air is turned on, the plungers rise, engage, and air is admitted to whichever one of the combustion chambers is at the proper point in the cycle. Then as the lay shaft revolves the cams engage one after the other, admitting air into the proper combustion chamber. This continues until one cylinder "catches its ignition," which takes place in one or two or three revolutions, very rarely over five. The instant a cylinder picks up its ignition a check valve in the air supply line closes automatically against the pressure. Everything is automatic, and it only requires the opening of one air valve and one gas valve to bring the engine up to speed.

H. C. Cronemeyer, Member—Will two gas engines drive alternating current generators with 60 cycles? In this particular case I notice it is 25 cycles.

J. R. Bibbins—I think there is no question about that. We have more 25 cycle engines of large size in service, but most of our small engine work is on 60 cycle systems. The permissible angular variation of the engine is, of course, always the determining factor and may be predetermined by the aid of inertia and crank effort diagrams. Usually a spring coupling has been used with 60 cycle work, but in 25 cycle work the engines are solid coupled to the generator. We have quite a number of 60 cycle plants in strictly power service. Lighting work is much easier on the plant.

B. Rutherfoord, Member—What is the consumption of gas in cubic feet per kilowatt hour, and what is the type of ignition?

J. R. Bibbins—There is no means of determining the kilowatt hour consumption accurately, that is why I took the car mile and ton mile basis. The method of ignition is the familiar make and break, or "hammer break" style. Igniters are tripped in succession by a single lay shaft; there is a small adjustment on the lay shaft drive by which the ignition can be advanced or retarded when the engine is running. This is quite a desirable feature. A storage battery of six or eight volts in duplicate is always available for starting and for regullar ignition, also 100 volt current from a small dynamo.

K. A. Muellenhoff—You said you have not been able to make a second inspection of the engines. From the experience we have had on the other side that is an exceptionally long run or an exceptionally clean gas. Where the gas has the least trace of tar the engines have to be cleaned from time to time.

J. R. Bibbins—I do not doubt that, but I know of one plant operating on producer gas made from bituminous coal, with three cylinder vertical type engines, that runs 24 hours a day 365 days in the year. There are three units and each unit does not get more than three or four hours attention a week. There are considerable quantities of lamp black produced, but the fact that the plant is giving regular service shows that it is of no importance. Gasoline is used to some

extent in flushing out the mixing valves. Of course at Warren the gas is natural gas, but that is not the whole story. The method of lubrication has more to do with it than anything else. The St. Louis coal testing plant is regularly making 25 to 50 hour continuous runs on low grade bituminous coals with only hydraulic scrubbing of the gas.

G. H. Danforth, Member—Is it considered advisable to run such a plant with unskilled labor? From what information I can get on the subject there is no labor too good for them.

J. R. Bibbins—That is undoubtedly true in any plant, whether steam, gas or water. It is true with gas engines; the more skilled labor the better. But the conditions at this plant are such that skilled labor can hardly be obtained, and I am certainly within the bounds of truth when I say that with the exception of one man, the operating force could not have been more unskilled. This one man has been the main reliance; the other attendants grew up from the ranks in every sense of the word. And the fact that one of their number, a young man, was capable of taking the night turn regularly—and that in my experience is where most of the trouble is likely to happen—shows how soon they are able to educate themselves and how little difficulty a gas engine offers to an intelligent man.

H. M. Scheibe, Non-Member—Is graphite used to any extent in these large plants for lubrication?

J. R. Bibbins—Not on these particular engines. I believe graphite is used on some engines. At least in a plant I visited I recall a method of introducing graphite in the air inlets of the admission valves, it being drawn in by the suction.

A. Stucki, Member—Why, in the large sizes of gas engines, has the horizontal type been mostly adopted?

J. R. Bibbins—Mainly because the vertical single acting type in large sizes becomes so cumbersome that the design is not best suited to large cylinders. Expansion troubles and the like come in. The double acting engine is by far the best type suited to heavy duty work in large sizes.

In regard to the producer plant, I recently had the pleasure of analyzing some results from the plant just mentioned,

and as I recall it the average coal consumption, over a period of several months, varies from 1.78 or 1.8 pounds to about 2.5 or 2.6 pounds per kilowatt hour. This was only a small industrial plant; with an average load factor of about 60%, using a fair grade of bituminous coal, the average efficiency, on a basis of gross heat consumption, was about 13%. On especially heavy day runs it has averaged 15%. This is gross thermal efficiency of the entire plant from coal pile to switchboard. Compare with modern steam plants and you will find very few of them get above 10%. The gas engine itself is capable, of course, of turning into work from 23 to 28% of the heat delivered to it, while the producer is capable of giving an efficiency of 60 to 80%, so that the plant as a whole is very much more efficient in coal consumption. Even in natural gas territory producer gas is so cheaply produced that sometimes it will be in favor. On the other hand you must not forget that fixed charges on gas producing plants operate to reduce the benefit which it might otherwise have over steam, and this is an important thing to take into consideration. In a district where the very cheapest coal is available it might occur that the gas engine would not come out best in the long run on account of the fixed charges, especially in small sizes.

A. Stucki—Are there many successful gas producer plants using bituminous coal now in existence?

J. R. Bibbins—There are plenty of them in this country alone, mostly of the double generator type with intermittent down draft—the Loomis-Pettibone type. The Mond system is also suited to bituminous coal, especially with cheap grade coals, and is much in use abroad. Successful plants using bituminous gas are operating at the Winchester Repeating Arms Co., New Haven, Conn.; San Louis Potosi, Mexico; the Gould Coupler Works near Buffalo; Sayles Bleacheries, Saylesville, R. I.; Atha Steel Co., Newark, N. J., etc., all equipped with gas engines of either vertical or horizontal design. At Rockland, N. Y., there is a large central station operated in connection with the Ramapo Iron Works. I do not think there is any question as to the success of the producer system as a whole.

B. RUTHERFOORD—For what sized engines was the consumption of coal 2 lbs. per boiler horse power?

J. R. BIBBINS—For comparatively small units, 235 brake horse power.

B. RUTHERFOORD—With 1,000 horse power units the consumption of coal would be lower than that?

J. R. BIBBINS—We would expect so, although the small gas engines give better duty in comparison with large engines than small steam engines.

W. M. HAMPTON, Member—As I superintended the installation of the Warren plant I can perhaps give some information regarding its operation.

It has been asked, how long a time is required to put the Warren plant in operation. I have frequently seen both engines brought up to speed from standstill, put on the line and load taken in 4½ minutes. The first engine was started October 19, 1905, without any previous preparation. In fact we did not "break her in," as is usually the case with steam engine plants; we simply started up, took the load and kept the load on the first engine for seven hours before it was taken off. When we shut it down there was no sign of heating in any place. The second engine was started about six weeks later, under almost similar conditions, but instead of seven hours we kept the load on seventeen hours, with the same results as with the first engine. After that we ran both engines in parallel with apparently no trouble. During that time we had but one 40 minute shut down, due to a slight mechanical defect which could not be foreseen in the shop. After we got that repaired we ran without any trouble whatever.

The problem of help in the Warren and Jamestown plants is a serious problem. One man was capable of running the station, but we had a lot of trouble getting the other fellows whipped into line. We had to take the ordinary laborer, as skilled gas engine labor is at a premium in this country. We have not got operating engineers educated to the highest point in gas engine work yet, although it does not take any

better class of help to operate gas engines than you would place in any well ordered steam plant, but when you take a man who has worked in the woods all his life time, put him in a plant such as the Warren plant and in a few months develop him into a man capable of taking charge of that plant and operating it on the night watch, it speaks very well for the gas engine end of the business.

B. Rutherfoord—Did the 4½ minutes required to start the engine include the synchronizing of the machines?

W. M. Hampton—That included the whole operation from the time of starting to the delivery of power to the line.

J. R. Bibbins—This record of starting is not as extraordinary as that held by the Philadelphia fire service pumping station, which supplies the business district with water under high pressure for fire purposes. In this plant the gas engines are direct geared to triplex pumps. Normally the plant stands idle, being started on signal from fire headquarters. For a period of one year the average time of getting the plant in service was very close to one minute, far ahead of the hose wagons. I have repeatedly seen the 300 horse power units started cold, the engines brought up to speed in about 30 seconds, and the pumping load put on by means of throttling a by-pass overflow valve so that the engine would be delivering water at the required pressure in 40 to 50 seconds; and this without any effort whatever.

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PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXII OCTOBER, 1906 NO. 7

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

*COKE OVEN CONSTRUCTION.

†W. M. JUDD.
Member.

In the limited time available this evening, it is possible only to give a brief description of coke oven construction as carried on at the present time, further limiting this description to the common or "bee-hive" type of oven.

As the necessity for using coke obtained from bituminous coal was forced upon the iron manufacturers by the disappearance of the forests from which their supply of charcoal was obtained, it was natural that the method of its manufacture should have been evolved from the methods previously used in making charcoal. Thus probably the first coke in any quantity was burned from coal piled in heaps on level ground, with suitable flues through the piles built of lumps of coal, refuse coke and slabs of wood for igniting the coal and regulating the supply of air, the whole banked with earth. I have seen a fair quality of coke produced in this way not more than six years ago.

* Meeting of Structural Section, September 25, 1906.

† W. G. Wilkins Co., Westinghouse Building, Pittsburgh, Pa.

A small separate kiln built entirely of brick was the next step in advance, and from these seperate kilns, by the grouping of the kilns in single or double lines, covering the brick work with earth, to retain the heat and building masonry retaining walls for the support of this earth covering, the bee-hive oven as it is built to-day was evolved, and in its essential features has changed very little in construction from its earlier forms.

The process of coking coal consists briefly in driving off by heat the gaseous constituents of the coal leaving the fixed carbon and ash. As this process is carried on in bee-hive ovens the coal is charged through the trunnel head and spread to a uniform level, the drawing door closed with fire brick plastered with loam, with the exception of an opening near the top for the admission of air the width of which is decreased as the coking process proceeds. It ordinarily requires forty-eight hours to complete the coking process, when the brick are removed from the door, the coke quenched with a stream of water played over the coke within the oven, the coke drawn and the process repeated. After the ovens are once heated the coal is ignited by the heat of the oven walls. It is important, therefore, that no more water shall be used than is necessary to quench the coke, and that the oven be re-charged as soon as possible.

As illustrating, however, how long the heat will be retained in a well built oven properly banked, I would cite a case that occurred the past summer where ovens were charged after being banked for four months on account of a strike, and almost without exception the coal was ignited by the retained heat of the ovens.

To meet the requirements of this process the bottom must be smooth, the liners, or fire brick up to the spring line, and the door jambs must be able to withstand the abrasion of the coke drawing tools, the crown brick and trunnel head must be able to resist the high temperature produced by the combustion of the gases given off in the coking process, the stone and mortar for the face wall must be of a quality that will not

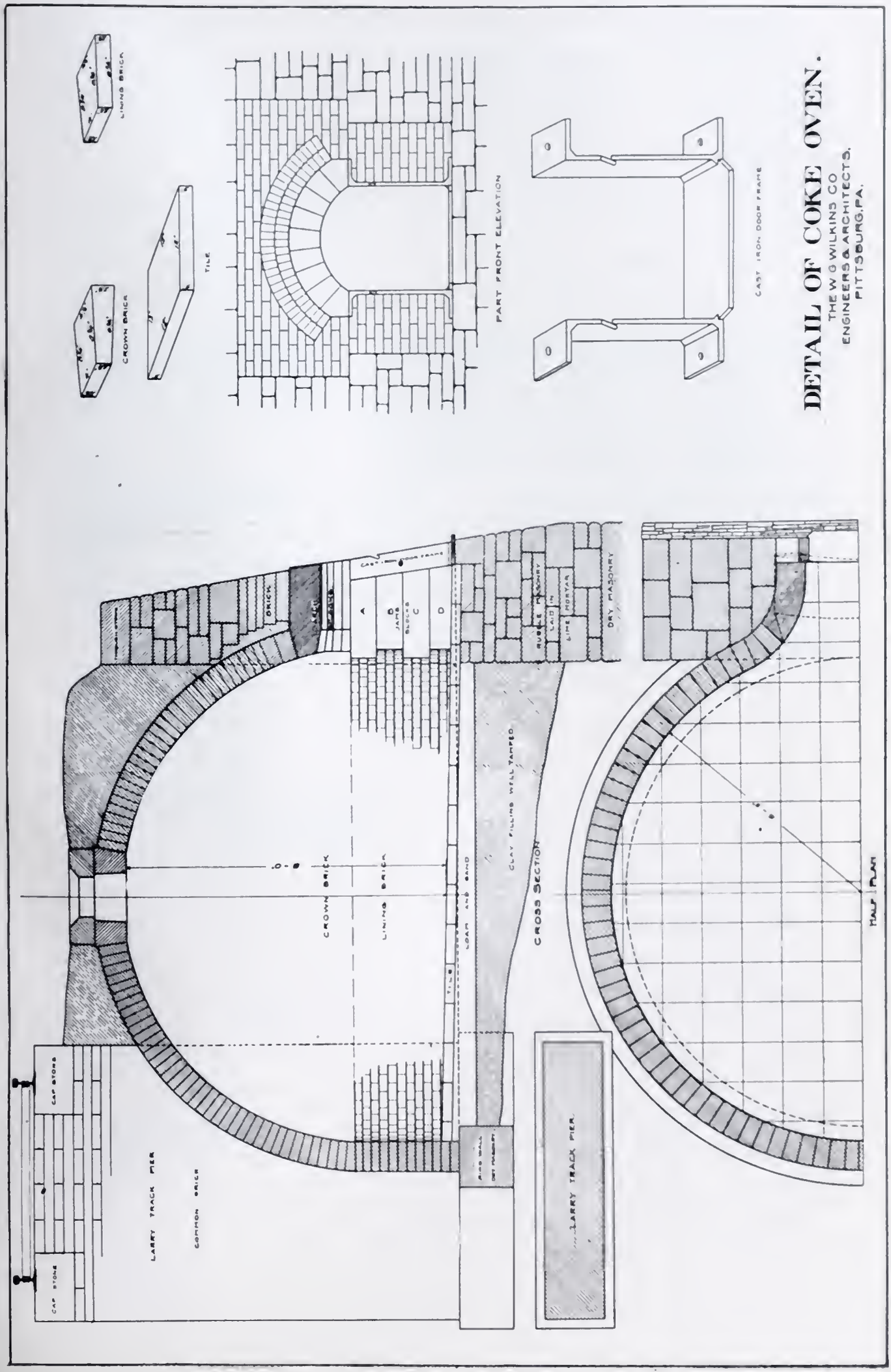
DETAIL OF COKE OVEN.
THE W G WILKINS CO
ENGINEERS & ARCHITECTS.
PITTSBURG, PA.
LINING BRICK
CROWN BRICK
TILE
PART FRONT ELEVATION
CAST IRON DOOR FRAME
CROWN BRICK
LINING BRICK
LOAM AND SAND
CLAY FILLING WELL TAMPED
CROSS SECTION
RUBBLE MASONRY
LAID IN
LIME MORTAR
DRY MASONRY
HALF PLAN
CAP STONE
CAP STONE
LARRY TRACK PIER
COMMON BRICK
LARRY TRACK PIER

FIG. 1.

disintegrate under the action of heat or the weather, the earth filling must be a material that will not fuse, and the whole construction must provide for the expansion and contraction caused by the sudden changes in temperature when the coke is quenched with water.

The detail plan of the oven, Fig. 1, shows the construction usually followed. It is advisable to have the oven seat come in solid ground. When this is possible a trench is dug 8 inches to a foot below the oven seat and a ring wall 18 inches wide of dry stone masonry is carried up to oven seat. In the same manner when the face wall of ovens comes in solid ground a dry wall 8 inches to a foot high is built before the mortar masonry is started, these dry walls serving as drains to keep any ground water below the level of oven seat. But it is very seldom possible to secure a location such that all ovens can be started with oven seat grade in solid ground. In this case the dry masonry rings are carried from solid ground to oven seat and the dry wall under face wall to within a foot of yard level, then the inside of rings and pockets between rings, which are shown in Figs. 2 and 3, are filled with clay tamped in thin layers as the stone work is carried up. Over 20 feet of dry work below oven seat has at times been necessary.

The liners, the brick for the cylindrical portion of the ovens, 2½ inches thick, 9 inches long, 4 inches wide on the inside and diverging on the sides approximately on radial lines, are usually a fire clay brick. The crown brick tapering both on the sides and the beds were formerly made of fire clay also, but in recent years either a clay-bond or lime-bond silica brick has been found to give better service, though fire clay crowns have by no means been entirely discarded. Formerly a thin mortar of loam was used for laying up both liners and crowns, and as a general rule the liners are still laid with loam, but it is the almost universal practice now to lay up the crowns with fire clay. A good quality of loam can very frequently be procured from the creek bottoms near the work, and that it is a cheap and satisfactory material is proven by many old ovens which have been in service for years, but the

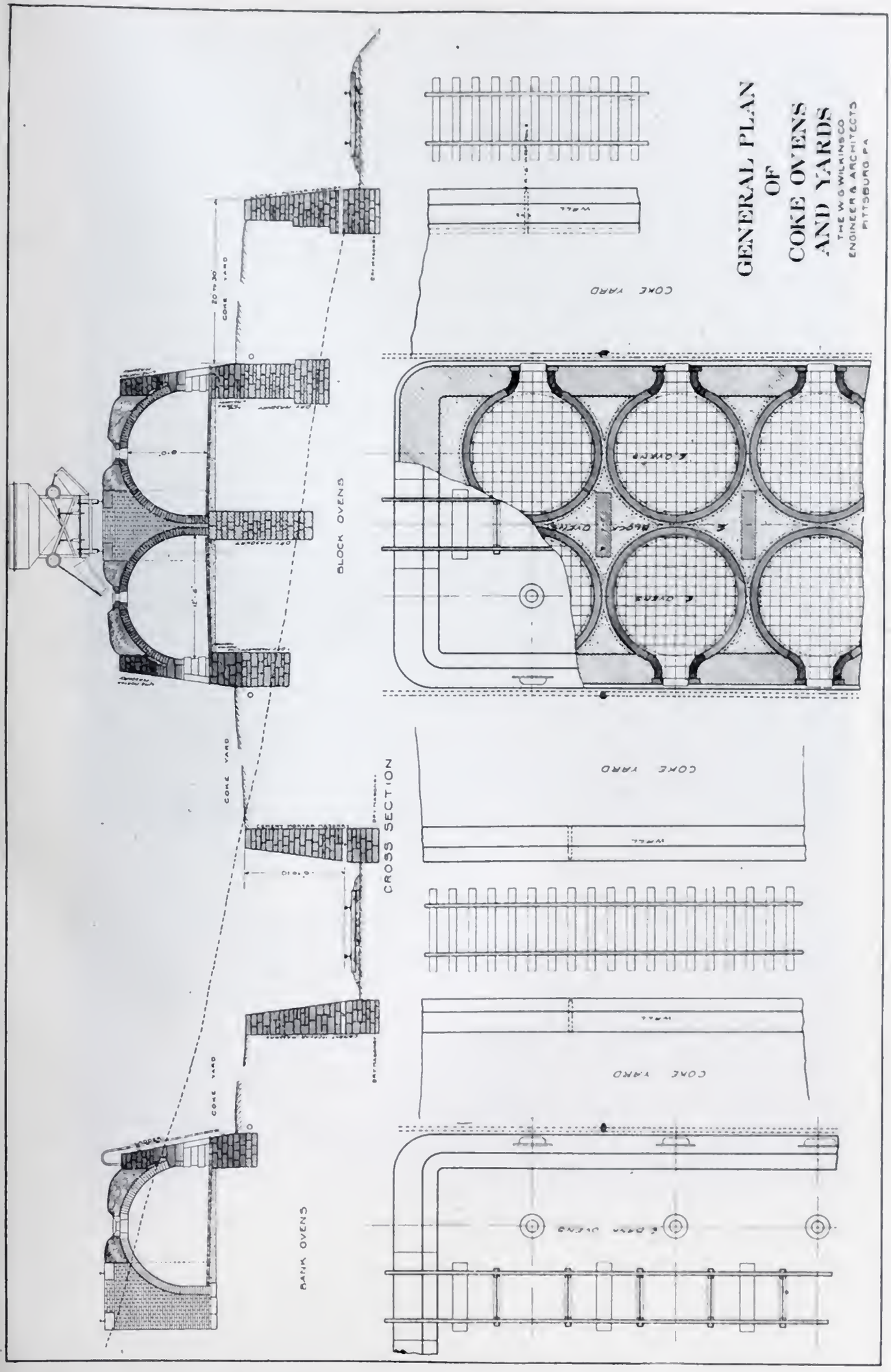
GENERAL PLAN
OF
COKE OVENS
AND YARDS
THE W G WILKINS CO
ENGINEER & ARCHITECTS
PITTSBURG PA
BLOCK OVENS
CROSS SECTION
BANK OVENS
COKE YARD
WALL

FIG. 2.

presence of any considerable quantity of lime or iron will cause it to fuse and run out of the joints, or flux with the brick causing them to spall. The more uniform quality of fire clay, which must be very finely ground, and the closer joints that can be laid with it have led to its adoption for the crowns. A sweep swung from a grade stake driven to spring line grade at the center of the oven, is used in setting the crown brick.

Fig. 3. Masonry up to Oven Seats.

The building of the oven proper is carried on in three stages; "liner high," up to the spring line, Fig. 4; "scaffold high," as high as a man can lay the brick standing within the oven, Fig. 5; and "crowned out," the completion of the oven from a scaffold placed inside of it.

For the jamb blocks, skews and arch blocks forming the door there are quite a variety of patterns in use, but all following the general lines of the detail drawing.

The trunnel block or ring has usually been made of a single piece of fire clay and has frequently given trouble by

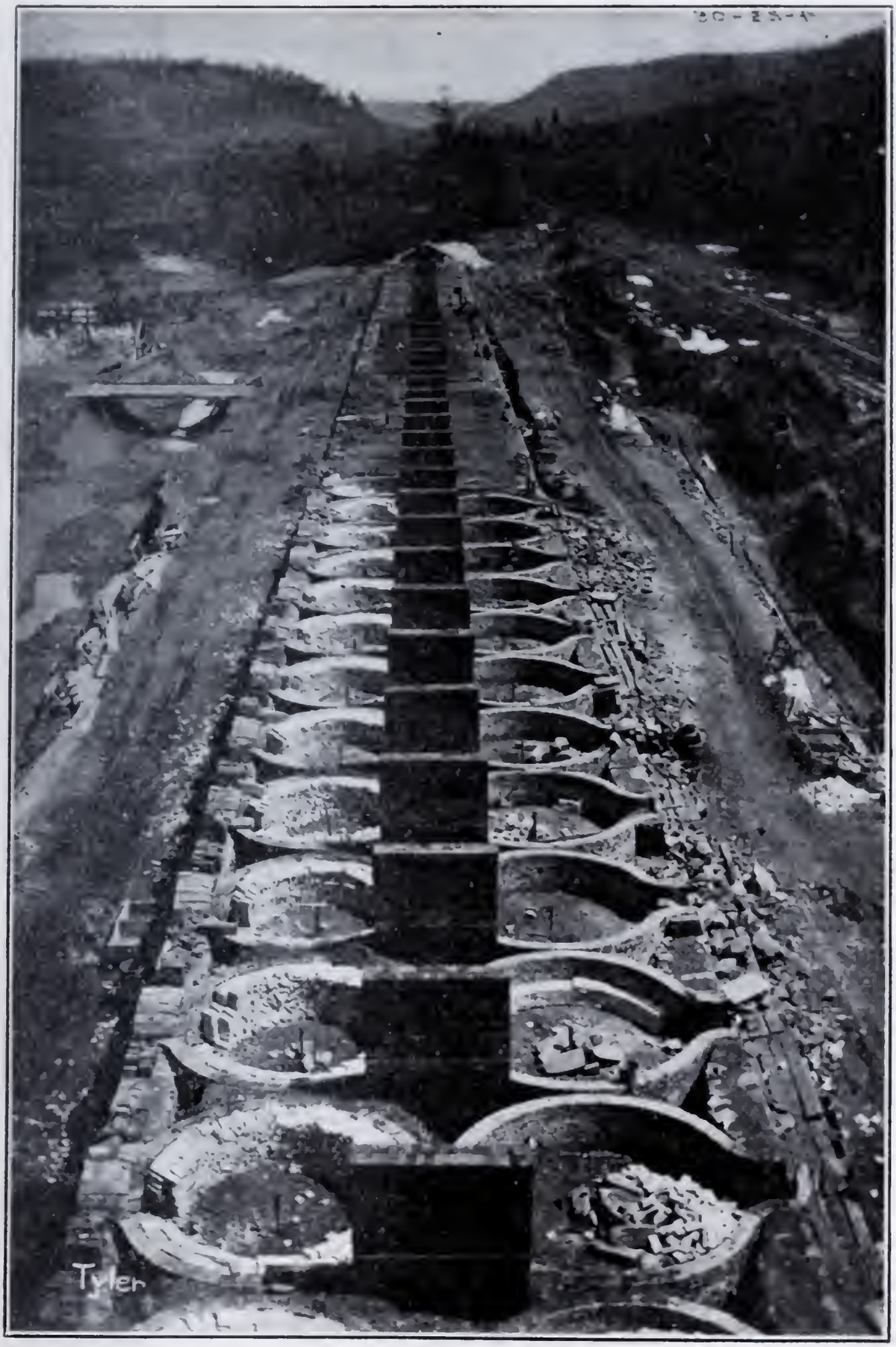

FIG. 4. Ovens "Liner High."

breaking in several pieces and falling, or spalling off in small pieces, into the oven. A ring made of several sections of silica of the same quality as the crown brick is now being used—from 8 to 12 pieces to a ring—but has hardly been in service long enough to prove whether it has entirely overcome the troubles encountered with the clay ring.

The upper clay trunnel block, which protects the ring proper from abrasion by the coal in charging and enables the filling to be carried higher over the crown, is used when the silica ring is adopted and is a good feature in any case.

Laying the bottom tile is the last step in the construction of the oven proper. The fire clay tile, 12 inches square by 3 inches thick, are laid on a bed of sand or loam with a slope of 4 to 5 inches from the back of the oven to the door to facilitate the drawing of the coke and the draining off of the water used for quenching.

The outside of the ovens are plastered with a coat of loam mortar as soon as completed to protect the brick work until the covering is finished. The face walls are built of a sandstone that will not spall when heated. A stone with flat beds and varying in thickness from 4 to 8 inches is sought for the oven wall and is finished with a rough coping 6 to 8 inches thick. Lime mortar is used for laying up the oven walls. Frequently the lime used is made from the native lime stone burned in piles on the ground near the oven location.

For the filling around the ovens "liner high" the clay is shoveled in from the yard and well tamped and then the ovens are usually crowned out before any more filling is done. Above the liners the filling is not tamped, but is leveled sufficiently to prevent the crowns from being distorted by unequal earth pressure. Usually a roadway is constructed to the top of the ovens, the trunnel heads are temporarily covered and the covering over ovens completed with carts in the same manner as a railroad fill is made. The material used for covering should be tested from time to time, as the presence of fusible ingredients has ruined many ovens within a few months of their completion. Chemical analyses of the clays are some-

FIG. 5. Ovens "Scaffold High."

times taken before construction work is started, but a fairly satisfactory field test can be made by subjecting a ball of the material to the blast of an ordinary blacksmith's forge.

That portion of the oven wall immediately adjoining the doors is built of common hard burned brick, an arch of two or three rings being thrown over the fire clay arch blocks. This construction takes the weight of the wall off the arch blocks and aids in repairs as the jambs and arches can be taken out and replaced without disturbing the walls.

The cast iron door frame is made with the same batter as the face of the oven wall and is anchored to the masonry with wrought iron rods. The upper brackets carry the outer end of the fire clay skew-backs. The door frame protects the jamb blocks to a large extent from the wear of the coke drawing tools. In the notches in the sides of the frame is placed a rod which serves as a fulcrum for the coke drawing tools.

The piers which carry the larry track are built either of rubble masonry or common hard burned brick. The best construction is to build them of rubble masonry laid in lime mortar up to oven seat and of brick above this level. The piers are usually 18 inches wide and 7 feet long and are topped off with a sand stone capstone under each rail of the larry track. As the piers in a standard 12 foot 6 inch oven are 14 foot 6 inch centers the rail acts as a girder between piers, though receiving a little support from the earth covering.

The general practice has been to use a standard railroad section tee rail, 80 to 100 pounds, but a more rigid track with less weight of steel is secured by the use of the 7 inch high, 70 pound street railway section rail. Two cast iron ties are used between consecutive piers with lugs bolted over the flanges of the rails to hold the track to gauge. When the 7 inch high rail is used tie plates are also bolted between the webs.

Several considerations enter into the construction of the yards and considerable variation can be noticed at different plants.

If a constant car supply from day to day could be counted

FIG. 6. Ovens "Crowned Out."

upon a width of yard just sufficient for the operation of the coke drawing tools and the passage of the ash carts would be all that would be required and a yard 12 to 15 feet wide would be sufficient. But the car supply is far from regular even in the most favorably located plants, and the operator who would avoid banking his ovens and, in turn, stopping the operation of his mines, must provide room for stocking coke, therefore, the yards are made 25 to 30 feet wide where possible.

The hand methods of loading are either forking into coke barrows and wheeling into the cars or forking from stock piles directly into the cars. Evidently the less grade there is between the yard and cars the easier the work is for the men. If box cars only were to be loaded a wall four feet high would be sufficient, and some of the older plants were thus constructed. Also, the earlier open top cars were low gondolas with side racks added and could still be loaded by the use of comparatively easy runways. As the capacity of cars was increased and a larger proportion of open tops built especially for the coke trade came into service, yard walls 6 to 8 feet high came to be the standard construction with runways cut into the walls occasionally for loading into box cars. In recent years the car supply for many plants has been almost exclusively steel or wooden rack cars, or steel hoppers 10 to 12 feet high, so that a great many plants built in the last five or six years have adopted a yard wall 10 to 11 feet high, sometimes building chutes in the walls at intervals for loading box cars. At many of the older plants the yard walls were built of timber crib work, and in some cases walls were dispensed with entirely, timber runways being provided at intervals for wheeling from the yard to cars. Then dry stone yard walls came to be the standard construction, and were indeed a great improvement in appearance and permanence over the crib work and the still more slovenly yard without any walls at all. With the adoption of the 8-foot and 10-foot yard wall stability demanded the use of rubble masonry laid in cement mortar. As the railroad tracks are frequently in solid cut the walls act more as revetments than retaining walls and can frequently

be built of quite light section. The introduction of the coke drawing machine, of which I will speak a little more fully later, will undoubtedly bring about a reversion to the lower yard wall.

It will be noticed how largely rubble masonry, either dry or laid in mortar, enters into oven construction. Fortunately suitable stone quarries are usually not difficult to locate in the vicinity of the oven location, but sometimes it is necessary to ship in practically all stone required on cars.

FIG. 7. Details of Oven Construction.

The method adopted by contractors in delivering the stone from quarries to the ovens depends upon the number of ovens to be built and the relative location of quarries and ovens. Usually all hauling is done in wagons, but sometimes quarries can be located so that there is economy in laying tramroads and hauling in cars either by horses or dinkey locomotives. Delivery of stone in railroad cars is very convenient for build-

ing the yard walls, but requires rehauling by teams for the oven walls and piers.

There is no physical reason why concrete masonry could not be used for the yard walls, but in the localities where coke ovens are usually constructed substantial rubble masonry can be built at much less cost.

Water for quenching the coke is supplied by a main usually 4 inches in diameter laid in front of the ovens with a 1 inch connection for attaching a hose for every two ovens. If possible the main in front of ovens should have tank connections at both ends so as to maintain approximately uniform pressure for the whole line of ovens. These tanks should not be over 50 feet above oven seat, as high pressure in the hands of careless or ignorant coke drawers may seriously injure the ovens.

One of the simplest methods of charging the ovens was by the use of drop bottom mine cars, running cars from the mine on a track over the center of the trunnel heads and dumping directly into the ovens. This method of course was limited to a small plant, as several cars were required for a single charge and the time required to shift cars was too great to allow of the extension of the system to many ovens. Some form of larry was therefore early adopted that would hold sufficient coal to charge a single oven. The drop bottom larry with the track straddling the trunnel heads was the earlier form, and there are some old plants which are still using this type, but the double side discharge larry is almost universally used now. In this form the steel coal holding hopper with sloping bottom is set sufficiently high above the tracks to discharge the coal through the adjustable chutes into the oven trunnels on either side, the track being laid at the back of the ovens on bank ovens and between the two rows of ovens on block ovens. The motive power for the larries has been successively, the mule, the dinkey locomotive and the electric motor. Nearly all the newer plants of any size are using the self-propelling electric larry, either equipping all larries with motors or using some plain larries as trailers.

At some plants of very few ovens the coal is dumped directly from the mine cars into the larry, but for a plant of any considerable size there must be a bin for the storage of coal so that the operation of the ovens may to a certain extent be independent of the mine and vice versa. The coke oven coal bin is too broad a subject to be taken up to-night and is merely mentioned on account of its bearing upon the next point of which I wish to speak—the location of the oven plant

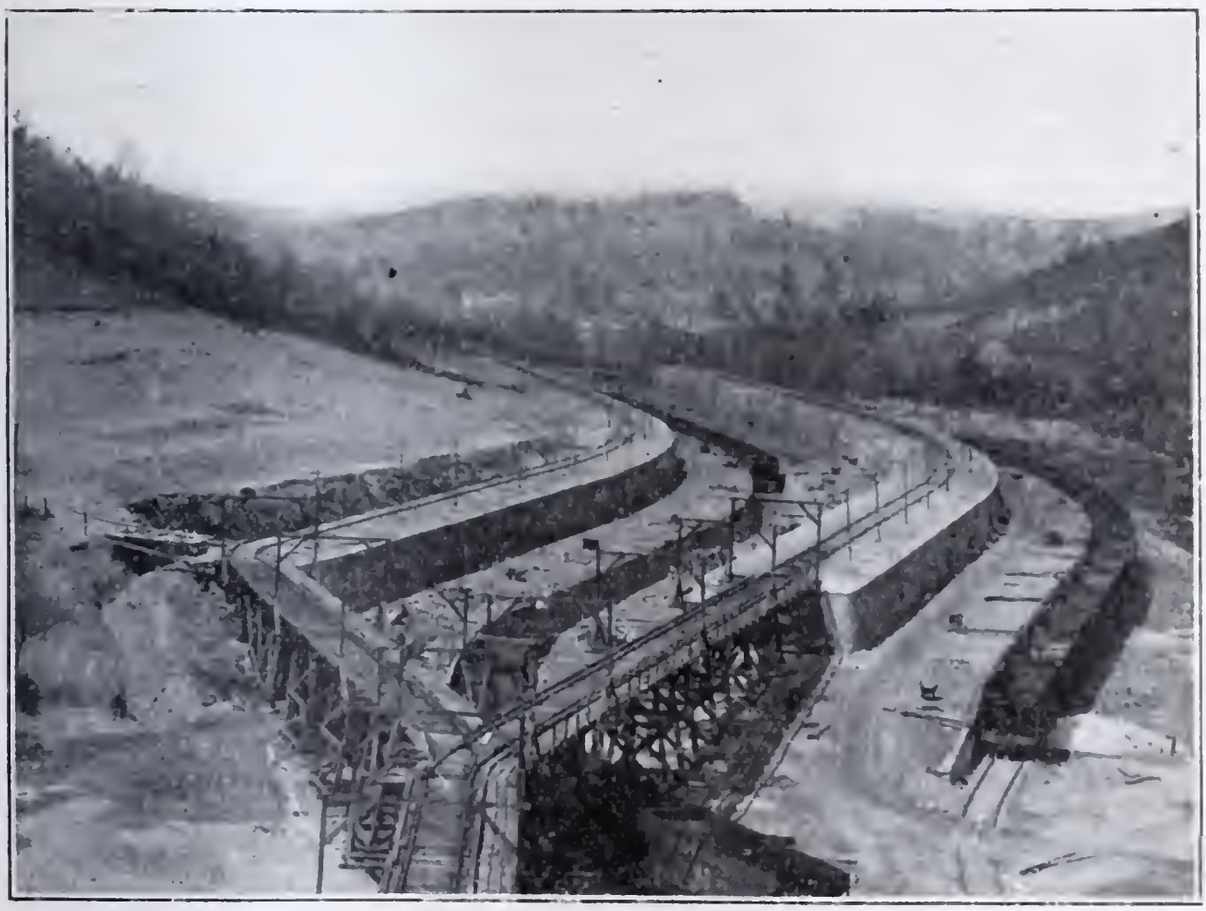

FIG. 8. General View of Completed Plant.

as a whole. This is a question that requires careful study by the engineer, and is influenced by several conditions in addition to those already referred to. The railroad connections that can be secured and the location of the loading sidings so as to give a grade of 1 to 1½% for shifting cars by gravity along the ovens must be considered in connection with the position and style of the coal bin adopted and the location

that can be secured for the larry track from bin to ovens. While an approximate balancing of excavation and filling is usually attempted, yet there may be economy in quite large waste of excavation in order to save in the amount of dry masonry required.

For plants not exceeding 100 ovens, bank ovens, that is, ovens built in a single line against a side hill, are usually the cheapest to build, as they can be located following approximately the contour of the ground so as to secure the most economical adjustment of excavation and masonry. It is not infrequently the case in narrow valleys with steep side hills that nothing but bank ovens can be built except at the expense of excessive excavation and masonry.

The drainage both of surface and underground water must be carefully provided for with bank ovens, and quite expensive work is required at times to divert springs which appear as the excavation is carried down.

As 100 ovens in line require approximately 1500 lineal feet of ground, it is easy to be seen that the extension of a line much beyond that limit will run one into difficulties. Even if suitable ground can be secured for a longer line of ovens and for the railroad loading track, the additional travel of the larry will cause delay in charging or the use of more larries. Block ovens, that is, ovens built back to back in a double line, occupying less ground and served by a single larry track located on the center line between the two lines of ovens, are therefore better adapted to the larger plants. A very economical arrangement where the ground is suitable is the combination of one line of bank and one line of block ovens, one loading track in this case serving for the bank ovens and one side of the block.

With the mine opening and the railroad tracks fixed the engineer may have very little latitude as to the location of the oven plant, but economy in construction and operation of both mines and ovens can be secured by a careful study of both surface and underground topography before locating mine openings, branch railroads and coke ovens.

A few points will now be touched upon in the operation of coke ovens which have had an influence on their construction in the past and may cause more radical changes in the future.

Anyone who has watched the method of drawing coke by hand must have wondered that some mechanical process had not been adopted to do away with such heavy and disagreeable work, and many experiments have been made and machines more or less successful have been built. At least one style of machine has come into quite extensive use in the past year or so, probably to a large extent because ovens already built can be adapted to its use with slight changes. This machine, operated by electric motors, runs on a track in front of the oven doors. A wedge-shaped shovel, operated by a rack and pinion sliding on the oven bottom, lifts the coke on the forward stroke and scrapes it on the back stroke onto a conveyor running parallel with the ovens, and a cross conveyor delivers the coke into railroad cars. This latter conveyor is adjustable so that any height of car can be loaded. It will be seen, therefore, that at a plant using this type of machine exclusively, if no provision were made for stocking coke, a yard only wide enough for the operation of the machine and practically on the level of the railroad tracks could be used. The safer plan, however, would be to provide some storage for coke and at least a low yard wall to render the reloading of stock coke less difficult. The only changes in the standard construction to accommodate this machine have been to provide wider doors to the ovens and increase the height from yard level to oven seat about a foot. The wear and tear on the ovens by the machine is quite noticeable, especially the abrasion of the jambs and tile.

The increasing difficulty of securing coke drawers and the decreased cost of mechanical drawing will undoubtedly lead to the wider adoption of coke drawing machines, of the type described above or of some other type, and it would indeed be strange if further modifications of the bee-hive oven were not made to better adapt it for the use of machines.

Even the casual visitor to a coke plant is impressed by the apparent waste in the smoke and flame issuing from every trunnel head, and to the engineer this constant loss of energy seems little short of criminal. In the by-product oven the attempt has been made to utilize as large a percentage as possible of the gases and heat given off in the coking process. No discussion can be entered into at this time as to the relative merits of the coke produced by the by-product ovens and the bee-hive type, or of the practical reasons that have prevented the erection of the by-product ovens at the mines to any large extent. A successful utilization of a portion of the waste heat, however, is now being accomplished at some of the more recently completed plants. This consists in using the waste heat for generating steam in the power plant. The construction adopted up to date has been to connect each oven of a line of bank ovens by a flue with a main flue located at the rear of the ovens, conducting the gases to the boilers. A very effective demonstration of the power wasted by the bee-hive oven is given at a plant recently completed where from the waste heat of 50 ovens all the electric power required, both for mining operations and at the coke ovens, for two plants aggregating 800 ovens is being generated at the present time, and at this same plant, within a short time, 100 ovens will furnish the power for the operation of five mines and coke plants, aggregating 1500 ovens. If a market for the power could be secured a further development of the use of waste heat for power purposes would doubtless bring about the making of other changes in the construction of the ovens.

Whether run of mine coal can be charged directly in the ovens, or whether the coal must first be crushed, or whether it must be washed as well as crushed, may have a very material influence upon the location of the ovens and some of the details of their construction.

DISCUSSION.

SAMUEL DIESCHER, Member—The production of coke in the bee-hive ovens is in several respects still in a very crude state. On the one hand the labor necessary in charging the oven with coal and drawing the coke is performed by hand, and, therefore, necessarily expensive. On the other hand the waste incurred by permitting the combustion products to escape is very considerable. A few years ago while serving on a committee investigating the smoke nuisance, I had occasion to inquire into the market value of the by-products gained from the coking process as carried on in the modern by-product ovens, and learned that it amounts to $25,000,000 annually in the Western Pennsylvania coke region. In continental Europe bee-hive coke ovens have been abandoned long since. The by-product oven is more economical than the bee-hive, not only because of the saving of the by-product but partly also because of its adaptability for the employment of machinery for drawing the oven as well as the greater yield in coke. The bee-hive oven never yields as coke over 66% in weight of the coal put in, while the by-product oven yields 75%. And there is further to be considered that the time involved in emptying, refilling and again starting a by-product oven is not over 15 minutes, while the bee-hive requires from two to three hours according to the capacity of the oven. According to information I have received from a trustworthy source, there is abundant capital ready for investment in by-product ovens if it can be shown that there is sufficient demand for the by-products—tar, pitch, gas and ammonia. In a plant comprising 100 ovens the cost per oven, including the chemical department, all complete, is $3,000.00. It used to be as high as $5,000.00 when the first ovens of this kind were being built in this country.

In relation to the machine Mr. Judd mentioned as now employed in drawing coke from bee-hive ovens, it would be inter-

esting to hear what difference there is in cost between drawing an oven by hand and drawing it by that machine.

W. M. Judd—I cannot state from memory the difference in cost, but the amount of labor required is reduced very materially. As has been stated, the drawing of two ovens is considered a day's work. A machine of this kind will take care of 25 or 30 ovens a day. It requires two men on the machine proper and usually two men that follow the machine as it will not draw the coke out of the corners, and a man to wet down the coke ahead of the machine. The machine in use so far has not been in service for many years and, as is always the case with a new machine, it is developing weak points which are being improved and strengthened from time to time. They are quite expensive to keep up, but there is no question that there is considerable economy in their use. This season when all the plants were short of coke drawers has brought a number of operators to the point of putting in machines.

The ovens have been developing in size. The earlier ovens were 10 feet 6 inches to 11 feet in diameter, and were gradually increased until 12 feet 3 inches was considered standard. Ovens have been built up to 13 feet in diameter. I think the general opinion now is that 12 feet 6 inches is about as economical as you can get. It depends a little on the coal you are going to use. With some coals you can use a larger charge and larger ovens than with others. The majority of the new plants I know of have been using a 12 foot 6 inch oven about 8 feet from high tile to trunnel head.

E. K. Morse, Member—There are a few points that Mr. Judd touched on that may perhaps be dwelt on a little more in detail. He has mentioned that the foundations of these ovens are filled in with clay. It is very plain to him why, but it may not be so clear to everybody. The filling in and tamping with good selected loam, or better, with clay, between and around and over the oven holds the heat, and if there is not two or three feet of good material under the hearth

there will be trouble with cold ovens. If the oven is not hot in the bottom good results are not obtained. If the oven is not properly drained, no matter how carefully it is built, let the water seep under it and there is trouble. That oven never can be kept hot, it never will fire right and it never will coke right. Inventors have been trying for years to devise means of drawing ovens rapidly in order to save time, money and especially the heat in the oven. There have been inventions by which the whole bottom of the oven has been turned upside down. All these things have been tried and will some day reach a successful end.

The author spoke also about the materials used in the lining. Years ago there was no trouble in this respect. For two reasons: the ovens were smaller and the amount of tonnage was not crowded to the maximum and a little beyond, nor running the gauge up to 2200° as is commonly met with to-day. Neither was an effort made to have the coke a little shade under 48 hours. It was 72 hour coke, which gives better coke and is a time to which all coke should be coked. Furthermore, the old brick makers used care in making fire brick. They would mine fire clay and spread it out and let it season for a year or two. One could not get them to grind it up and sell it immediately after mining. Nowadays they sell it while it is in the hill and try to get it out and in the oven and the money in the bank before it has time to weather.

Regarding the life of ovens, there is a set of ovens not far from here which they finished too late for that season and they were allowed to freeze and thaw before being fired. They lasted about three months. An adjoining set of ovens were finished about this time of the year, fired slowly, have been in use for years and are just about as good as new. Different companies are experimenting with silica brick, and as I am not fully posted on the subject, I would like to ask the author what his experience has been.

As to the size of the oven, my best information is 12 feet 6 inches. That seems to meet all the conditions. Some of the best coke of to-day is made from crushed coal, especially that

in the Klondike section and from there on across the Monongahela river. The use of by-product ovens in this country, so far as I know, is not general. At the Cambria Steel Company they say they got pretty good coke, they got all the by-products, but they were all just impure enough to be out of the market, and by the time they had exhausted their energies making their by-products pure enough for commercial purposes they were not making it cheaply. Consequently they would rather make coke and pig iron than by-products.

Without dwelling on the profit and loss account of our neighbors at Glassport, they have been able to sell their gas products to McKeesport and thereby relieve rather an embarrasing situation.

The style of oven is not necessarily bee-hive in all its details. There is a plant in my mind that was very successful and got an elegant coke, where they have carried the smoke and gases and fumes into a large flue, thence into a large brick lined stack nearly 200 feet high, and by drawing the smoke and all the by-products through the flue and stack, brought about complete combustion of the smoke and volatile matter. It required a nicety of management to prevent fusion and destruction of the fire brick linings of the flue and stack.

It has been my experience in the building of coke ovens, that the construction, such as the author describes as standard, is too cheap. The foundation is too cheap, the whole construction above ground level is too shallow, and I believe there is money saved in using a better grade of workmanship. One well known company in this vicinity is using concrete face walls and wharf walls alongside the steam railroad tracks. I believe it pays, especially where there is a permanent plant and kept in operation for an indefinite number of years. Where the plant is handy to the furnaces the wharf wall is made only 10 or 11 feet wide, which is a very great advantage, permitting the coke being removed direct from the oven to the car. Where it has to be handled, as in the Connellsville region, depending on car supply, the wharf wall must be made to provide storage. That means handling

two or three times, breaking up the coke, destroying its capacity to carry a burden in the furnace and adding to the cost of production.

W. M. Judd—With regard to silica brick, I would say that the experience we have had with them in the last few years has been very satisfactory and we are specifying them altogether for new work. They seem to stand the heat in the crowns and do not give the trouble from spalling that often comes from fire clay brick. It is a very difficult matter to secure uniformly good fire clay brick for crowns. Even from manufacturers who have a very good reputation, shipments will be made that do not stand the service in the oven. I know of but few instances where silica brick have been used for liners, except as an experiment. They are, of course, a softer brick and do not stand the abrasion of the drawing tools as fire clay brick will. Of course the liners do not have to withstand as high a degree of heat as the crown brick and fire clay liners have been very good in service. There are brick and brick, and everyone has had experience with bad brick.

As to the more permanent construction of ovens, I think that is a point well taken, although with yard walls as they are being laid now, with Portland cement mortar, they can be built very substantially. As a general thing in the vicinity of the coke ovens there is sand stone that makes a very cheap and yet a very good class of masonry. Of course, if an operator can see far enough ahead to know that his plant is going to have a long life, he can afford to put in the more expensive construction, and there may be economy in it. I have no doubt there would be in a long lived plant. But the construction that is usually carried out gives results that are sufficiently satisfactory.

There is always trouble in one point, the tile. No matter how carefully the tamping is put in the bottom of the oven, the heat will contract it, there will be more or less settlement and almost invariably the tile will have to be taken out and relaid after the oven has been in service a time.

E. K. Morse—There is one thing I intended to mention here that may be interesting, and that is the use of concrete for face walls. In following around the arch of the face wall there is a good deal of expensive work as compared with the other parts that constitute the coke oven other than the brick lining. A section of this was built of concrete. It was mixed about 1-3-9 portland cement and gravel. For the first year the result was splendid. There was not by any odds the number of cracks that appear in masonry ovens. It resisted the expansion and contraction that takes place in an oven with a great deal more efficiency than the ordinary masonry faced wall. The oven was stronger, held its position, the brick work was supported better and the clay lining between the concrete and the brick lining of the oven was held firmer and it was believed to be entirely successful and exactly what had been sought for. The second year, however, two years after it had been in use with constant firing and pushed hard, it was opened up and to the surprise and disappointment of the management the concrete had crumbled to dust and could be scooped out of the solid wall with your hands. In other words a heat of something like 1800°, 2000°, 2200° and sometimes 2300°, (I have known it to go as high as 2500°) and then cooled down so that a man may wrap his coat around him and go inside an oven between changes if he is quick about it, will in time completely disintegrate any portland cement concrete exposed to such extremes of heat and cold.

W. W. Keefer, Member—I understand Mr. McDonald for an experiment built two or three ovens in West Virginia 20 or 25 feet diameter. Is there any reason for limiting ovens to 12 or 13 feet other than the physical reason of drawing the coke? If an oven was 20 feet in diameter, wouldn't it make just as good coke?

W. M. Judd—I knew the ovens had been built for experimental purposes, but I never heard what results they got from them. I suppose the size of an oven is somewhat arbitrary. I know of one plant where the ovens are built 13 feet

diameter, but their experience is that they have not gotten any larger yield from these ovens, or secured any better coke than from the 12 foot 6 inch ovens. There are three plants under this one management where they have 12 foot, 12 foot 6 inch, and 13 foot ovens, respectively, and they have found from experience that the 12 foot 6 inch ovens give the best results. They secure a very little larger output and the cost of charging and handling the larger amounts is somewhat greater.

W. W. Keefer—Isn't there also a question of ash?

W. M. Judd—There is. The distribution of air for burning volatile matter, as the ovens are built with the same size door, is a little different as the oven increases and the height of the crown is raised, and just the proper relation between the height of the crown and the diameter of the oven comes into consideration, so that it would require probably quite a series of experiments with any particular diameter to secure the best results. Take the ovens being built for the Frick Coke Co., they have a little lower crown this year as they think they will get better results out of the oven. I do not know that any of them have been in service yet to see whether there is any material difference.

Samuel Diescher—About 25 years ago there was a plant of bee-hive ovens in operation near Steubenville, Ohio, which were 14 feet diameter. I asked the owner how he liked them and he said if he had to do it over again he would not build them so large.

W. W. Keefer—Why can't you use a 15 foot oven?

W. M. Judd—There are difficulties from the construction point of view. If you get much more than 13 feet 6 inches, you get too wide an arch with more pressure than the brick will stand. Either the oven will be too high or so flat that there will be a tendency to crush in, that is, following the ordinary construction of bee-hive ovens.

W. W. Keefer—Is there any reason at all why, if the oven is properly designed, they could not make just as good coke in a 20 foot oven as a 12 foot oven?

W. M. Judd—I should say there might be a difficulty in this size of oven as the question is whether you would get the proper distribution of air over your bed of coal. This is mere theory on my part. Of course the air as it comes in now passes over the coal and burns the volatile matter and passes out the trunnel hole. Whether with a small door in a 20 foot oven there would be a tendency to burn better in the center than on the sides, and thus not get a uniform quality of coke throughout the oven, I could not say.

Samuel Diescher—If large ovens are built as high in proportion to their diameter as ordinary ovens are built there may be trouble on account of their slow ignition, for this event is brought about chiefly by radiation of heat from the crown, and the effect of radiation decreases with the square of the distance between the source of heat and the material to be heated.

E. K. Morse—As I understand that subject, everything depends on the amount of clay that is over, around and under the oven, especially under it. I remember one case where furnace slag instead of clay was filled in until above level ground, as it was very much cheaper. There was about a foot of clay spread over the slag. When the ovens were fired their bottoms were cold, they never heated up properly and failed just that much in efficiency. One result was that the ash was increased for the simple reason that the ovens were slow in starting to roast. The object should be to keep the oven as hot as possible, get it drawn as quickly as possible, and if there was intelligent care used in cooling down an oven there would be a great deal of money saved. It is a common thing to see a man hold a hose over the cross bar and let it run. It may be playing for five minutes right against the super-heated brick instead of on the coke, which accounts for so much of the spalling off of the brick. The coke would be

cooled down ready to draw very quickly if care was used to distribute the water evenly. There have been a great number of patents gotten up for that, but nothing is as successful as the hose in intelligent hands.

F. A. McDonald, Member—What about the size of the coal?

W. M. Judd—Whether you have hard coal or a washed coal to begin with probably makes quite a difference in results.

F. A. McDonald—Isn't that true of the by-product oven? The furnace men say that the coke made in by-product ovens will not bear the same charge as an ordinary bee-hive coke?

W. M. Judd—That is true.

Samuel Diescher—As a rule the coke from the by-product oven is denser.

F. Z. Schellenberg, Member—I believe the best part of the coke is the portion that is condensed from the volatile matter, the carbon that is returned to the outside, the silvery, pearly part we see which we understand to be due to condensation from the volatile matter. If that portion of the volatile matter could be re-coked, instead of having a gas waste we would have an improved quality of coke.

In these ovens Mr. Morse speaks of with the high stacks, what becomes of all the condensed carbon? What becomes of the heat?

E. K. Morse—Everything is burned up and the heat is dissipated.

F. Z. Schellenberg—That is a pity. Why can't they recover the carbon?

E. K. Morse—I suppose they could, but the great thought, of course, is making pig.

F. Z. SCHELLENBERG—It improves the quality of the coke to condense the carbon on the coke.

E. K. MORSE—That may be, but you get too far away from the making of pig, that is all.

R. A. CUMMINGS, Member—I would like to ask Mr. Judd what the ordinary life of an oven is, and to what height do they charge an oven?

W. M. JUDD—The life of an oven is extremely variable. Some of them have been 10, 12 and 15 years in service, but they are exceptional cases. Usually an oven requires some little repairs in the course of a year or so. It depends very largely on the quality of brick that goes into it in the first place. The charge for a 12 foot 6 inch oven on 48 hour coke is about 6½ to 7 tons. For 72 hour coke they increase it to 7½ and sometimes as high as 8 tons. The ordinary larry that is used now holds about 200 bushels level full, and for a 72 hour charge it is heaped as high as possible and frequently side boards added.

A. STUCKI, Member.—We have heard that it is exceedingly desirable to keep the coke from breaking, and for that reason it strikes me that there is possibly an advantage in using steel coke racks over those of wood, now mostly in use, inasmuch as the coke could be delivered into the cars without being quenched so much. Would such a reduction in quenching not mean a proportionately less amount of breaking up?

W. M. JUDD—Your question is whether the coke could not be taken out without quenching it in the oven. Of course the less water that can be put on the coke and quench it, the better the quality of the coke. But in any case you must put on enough water to entirely extinguish any fire, otherwise your coke will catch fire in a steel rack as well as in a wooden one. It happens once in a while that coke that has not been sufficiently quenched is put in a car and catches fire.

The question of the breaking up of coke is, of course, one of the strong arguments raised against coke drawing machines.

There has not been any machine made yet that does not break up the coke to a greater or less extent. It would seem that this is not a very strong point, however, for by the time it is drawn from the oven to the yard and forked from the yard into a barrow, dumped from the barrow into the car and from the car to the yards or bins at the furnace and then reloaded into the furnace skip, it gets to the furnace anything but large coke at best. The furnaces are using coke drawn by machine and, as I understand, it is with very fair results.

A. Stucki—Is there any advantage in covering a coke car?

W. M. Judd—Some of the furnaces used to require that their coke be shipped in box cars or cars with tops. Of course the protection of the coke in transit is an advantage. But for furnace coke the use of cars with tops has been nearly abandoned. The Illinois Steel Co. when they first began getting their coke in the Klondike region installed a series of cars with removable roofs, intending to have all their coke covered in transit. Those cars are all in service now, but their roofs are over the bank.

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PROCEEDINGS OF THE

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THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

*HEAT DISSIPATION WITH ESPECIAL REFERENCE TO THE ANNEALING OF PLATE GLASS.

†H. K. HITCHCOCK.
Member.

In every engineering operation where heat is generated either by combustion, chemical action or the dissipation of mechanical, electrical or magnetic force, problems of cooling arise that are worthy of the most careful consideration. These problems are so many and diverse, however, that only those which have a direct bearing upon the annealing of glass sheets can be considered and keep within the limits of a paper of this kind.

It would seem to be a fact so simple as not to need demonstration, that a sheet of glass without appreciable thickness, no matter what its superficial area, would require no special arrangement for cooling, for practically all of its contained heat is at its surface and all that is required is to permit free radiation from both sides. For such glass, however, there is

*Meeting of Society, Sept. 18, 1906.
†Tarentum, Pa.

but scant demand. As the area of the sheet increases, its thickness must also increase to give it the requisite strength that it may successfully withstand the strains to which it will inevitably be subjected. Now, in proportion as the area and mass of the sheet increase, the problems involved in so cooling it that it may be soft, straight, whole and free from strain when cold, increase in number and complexity in geometrical progression, and it is the purpose of this paper to briefly discuss some of these problems as relating to heat dissipation.

As many of you may be in ignorance of the apparatus used for this purpose, it will probably be well to first describe it before discussing the action taking place during the annealing operation.

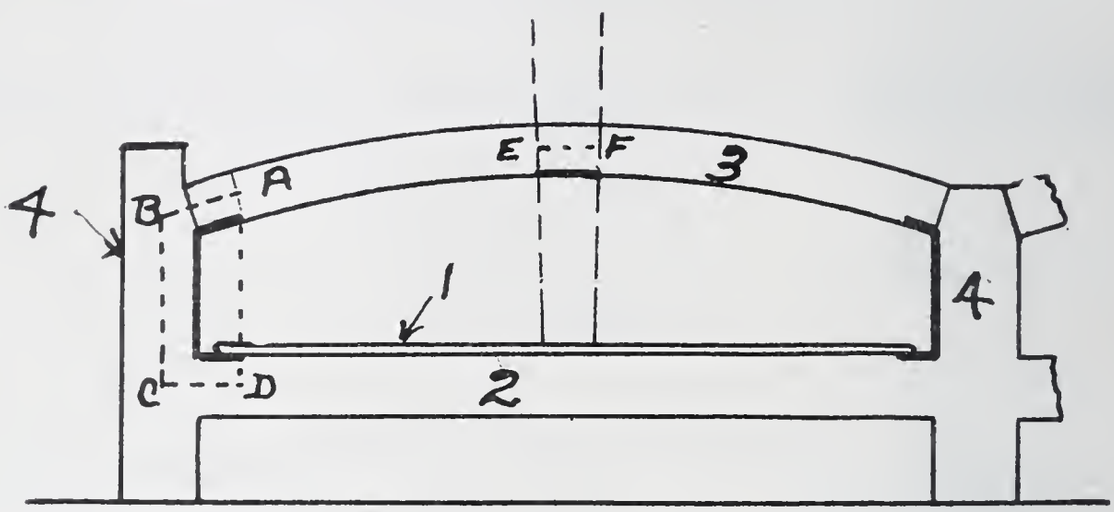


FIGURE 1.

The rough plates for polished plate glass are formed upon iron tables in much the same manner as our cooks form their pie crust, except that a huge iron roller makes but a single trip across the plastic glass to reduce it to the desired thickness. As this sheet lays on the iron table after its formation its under surface is very much colder than its upper surface, though it is all in a highly heated condition, so it is not only necessary to cool the sheet slowly enough as not to strain or bend it, but its temperature throughout must be thoroughly equalized.

This was done for many years in massive brick annealing ovens or kilns having a section similar to that shown in Fig. 1

and long enough to accommodate from one to four plates. The hot sheets were shoved into these ovens as soon as they had cooled sufficiently to permit of handling without bending or buckling. Each time the ovens were used they had to be carefully prepared for the reception of the plates, first, by dressing the hearth so as to insure a perfectly straight, even surface for their support, and then by heating them to a temperature slightly higher than the incoming sheet. When the sheets were safely stowed in their proper berths, the ovens

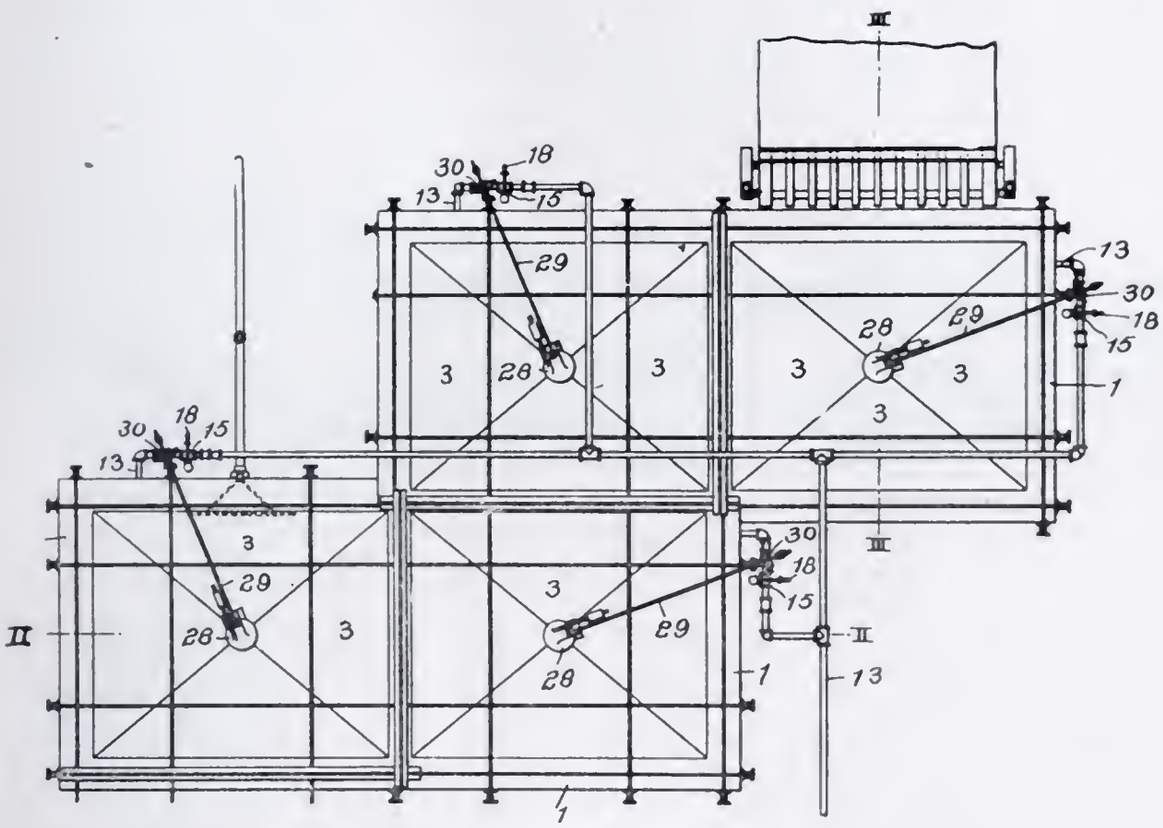


FIGURE 2.

were closed and sealed as nearly air tight as possible and then allowed to cool for several days, after which they were opened and the plates withdrawn. The fuel required to heat these ovens was enormous, being considerably greater than that required to fuse and refine the glass from which the plates were made. Aside from the inefficiency of this method, many difficulties had to be overcome due to the frequent heating and cooling of the hearths and arches and the resulting problems of expansion and contraction, as well as the problem of heat dissipation. The oven system of annealing might be called

a cycle system, and while probably over half of the plate glass now made is still annealed in this way, it is very rapidly giving place to the leer, which is, when operated to the best advantage, practically a continuous system. While the different forms of leers vary in their methods of handling and controlling the cooling of glass sheets, they all have a common plan, a series of ovens with plane hearths, similar to the annealing oven just described, having gradually reduced temperatures and arranged in zig-zag fashion to facilitate the shoving of the sheet from one oven to another. Such an arrangement of ovens is shown in plan in Fig. 2. A section on the line II—II being shown in Fig. 3.

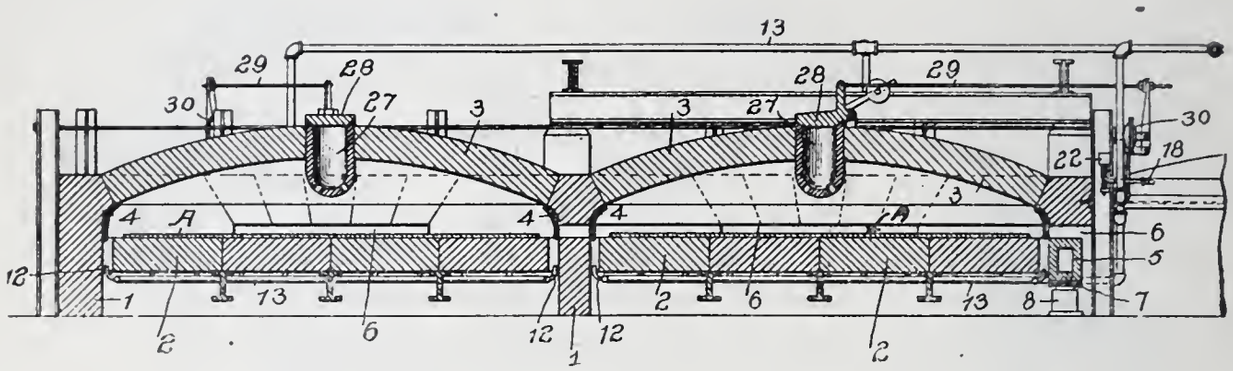


FIGURE 3.

At one side of the coldest oven is a long tunnel or runway, shown in section in Figs. 4, 5 and 6, having an arrangement for carrying the sheet from the hot or receiving end to the cold or discharging end, the scheme being to reduce the temperature of the glass, while still ductile and resting upon the plane hearths of the ovens, by shoving it from a hotter to a colder environment and, when sufficiently cooled to hold its shape, load it onto the carriers in the runway and then by advancing it from a hotter to a colder position finally reduce its temperature to that of the ambient air. The specific apparatus to be later described aims to provide:

1st, a means for cooling glass sheets without causing the strains ordinarily attendant upon the sudden introduction of the hotter glass into the cooler enveloping chamber; 2nd, to eliminate the distorting strains due to unequal cooling of the

various sections of surface of the sheet; 3rd, to provide such a mechanical means for advancing the sheet in the runway as will practically be fool proof and render impossible the distortion or breaking of the sheet from mechanically applied stress. In order to understand how the first of these objects is accomplished it is necessary to appreciate some of the laws of cooling and the various elements which enter into the phenomena of heat dissipation, with especial reference to such an arrangement as we are considering.

As we all know, objects at a temperature above that of their surroundings lose their heat energy; first, by radiation; second, by contact with their supports and the enveloping air or gases. The speed with which this loss of heat takes place varies in a complicated way according to their physical character, temperature and environment, the laws of which have been studied by various investigators who have proposed empirical formula satisfying more or less accurately the conditions surrounding their investigations.

Before taking up the laws of Dulong and Petit for cooling, which laws seem to be best adapted to the problems involved in the annealing of glass, let us consider briefly the progress of our knowledge concerning this phenomenon, beginning with Newton, who was the first to set forth views concerning it and whom, we find, had very accurate notions about heat and what actually occurs in the cooling of hot bodies. We find, for instance, in the Queries to his book on Optics, such pertinent expressions as in Query No. 6: "Do not black bodies conceive heat more easily from light than those of other colors do, by reason that the light falling on them is not reflected outwards; but enters the bodies, and is often reflected and refracted within them, until it be stifled and lost?" Also in Query No. 8: "Do not all fixed bodies when heated beyond a certain degree, emit light and shine; and is not this emission performed by the vibrating motions of their parts? And do not all bodies, which abound with terrestrial parts, and especially with sulphurous ones, emit light, as often as those parts are sufficiently agitated, whether that agitation be made by heat

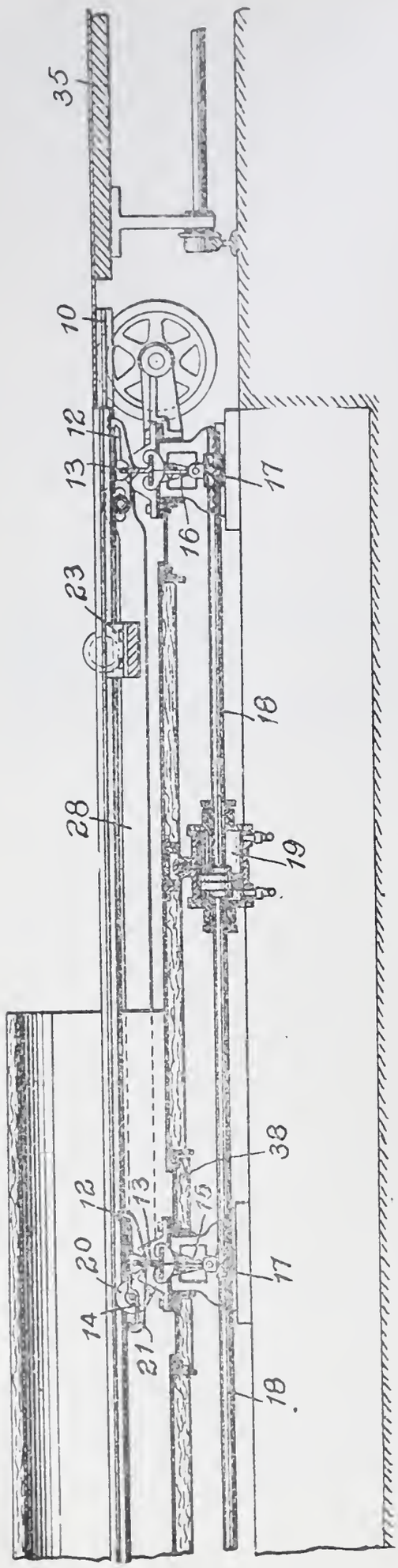


FIGURE 4.

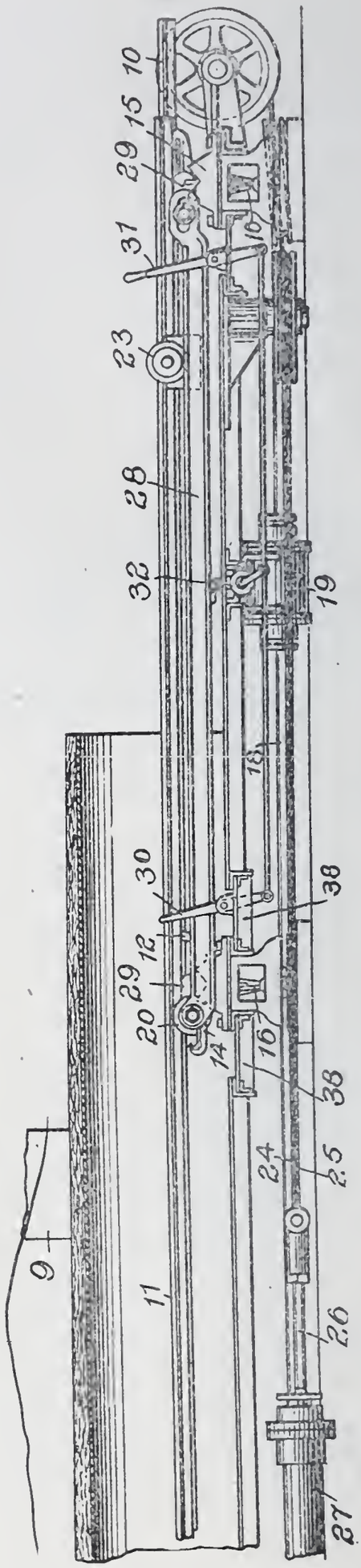


FIGURE 5.

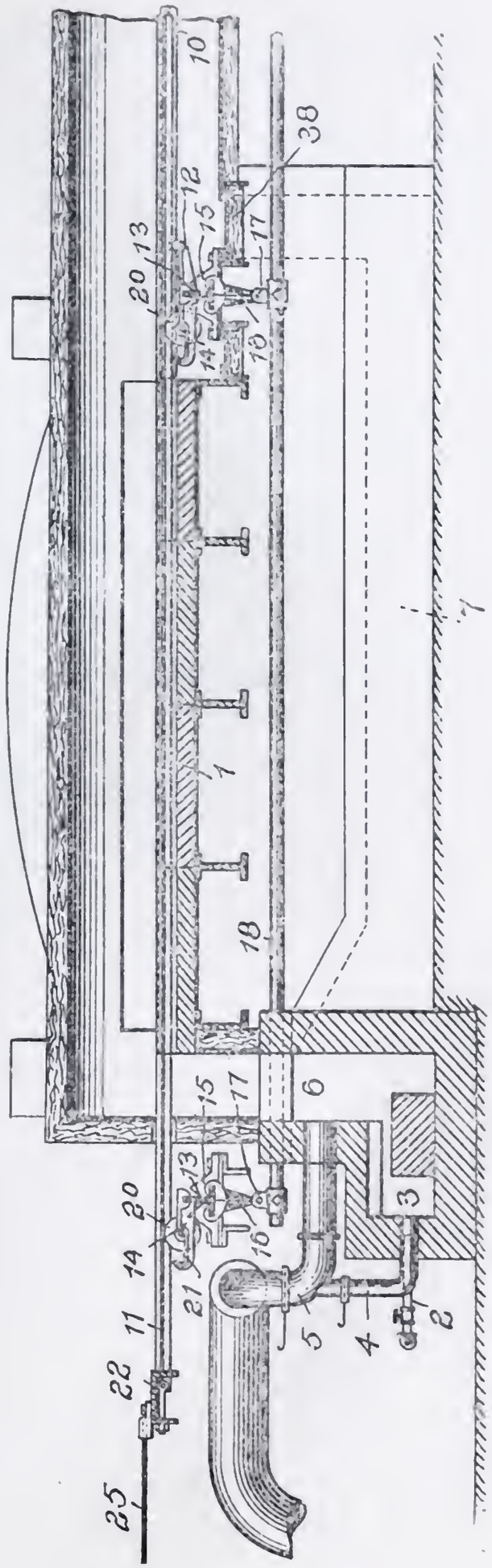


FIGURE 6.

or by friction, or percussion, or putrefaction, or by any vital motions, or any other cause?"

It is curious to note that while in his younger manhood Newton set forth what is now practically the universal idea, that heat is propagated by means of vibrations and waves, yet before he died he seems to have been converted to the corpuscular or fluid theory, which continued to be almost universally held in regard to heat long after it had been abandoned in regard to light.

He also distinctly recognized the fact that heat is propagated from a hot body to a cool one by vibrations of the intervening medium and enunciated the first empirical law of cooling, which he conceived to be; that a body subjected to the action of a colder one lost a quantity of heat each instant proportional to the difference of temperature between the hot body and its surrounding environment, which may be expressed by the equation $Q=M(T-T_1)$ in which Q equals the heat lost by a body at temperature T when surrounded by bodies of temperature T_1, M is a constant depending upon the body. He, however, failed to recognize, or at least remained silent upon the question, whether hot bodies not subjected to the action of cool ones radiated heat or not, and it was not until 1791, when Pierre Provost published in The Journal de Physique, Paris, his memoir on the equilibrium of heat in which he set forth his Theory of Exchange, upon which the modern notions of heat are largely based, that any real advance was made.

The century elapsing between the time of Newton and Provost had been largely taken up by an academic discussion as to the character of heat, with the best of the argument apparently on the side of the advocates of the fluid theory, and we find at the conclusion of a memoir published by Provost at Geneva in 1809, the following:

* * * * * "As stated below I propose to consider *caloric* as a specific fluid. I will represent the radiation of this fluid as an emission and never as an undulation. I believe this conception and this representation to be more conformable

than any other to the nature of things and founded upon the soundest principles of general physics.

"But if those who believe otherwise substitute waves for an emission they may be able, perhaps, to adapt to their opinions the explanations which I give for phenomena of this class. * * * * * "

He then sums up the results and conclusions arrived at as follows:

"Heat is a discrete fluid; each element of heat follows constantly the same straight line as long as no obstacle arrests it. Every point of a hot place is constantly traversed throughout by streams of heat.

"If we admit this constitution of heat, the following conclusions are inevitable:

"The first three require nothing further. The others require the assumption that heat is comparable with light in its movements of reflection and refraction.

"1st conclusion: Free heat is a radiant fluid, for, as at the surface of the body the heat becomes free, each point of the surface of the body is a center to which tend, and from which are carried, in every direction, streams of heat.

"2nd conclusion: The equilibrium of heat between two neighboring free spaces consists in the equality of the exchanges.

"3rd conclusion: When the equilibrium is disturbed, it is re-established by unequal exchanges. In a medium of constant temperature, a body that is hotter or colder acquires this temperature according to the law that *the periods of time being in arithmetical progression, the differences of temperature are in geometrical progression.*"

"4th conclusion. In a space of uniform temperature, if a reflecting or refracting surface is introduced it has no effect in changing the temperatures of any part of this space.

"5th conclusion. In a space of otherwise equal temperature, if there is placed a body which is either hotter or colder and if afterwards a reflecting or refracting surface be introduced, the points upon which these surfaces direct the rays emanating

from this body, will be affected by it, being heated if the body is hotter, or cooled, if it is colder.

"6th conclusion: A reflecting body, having been heated or cooled internally, will acquire the surrounding temperature more slowly than a non-reflector.

"7th conclusion: A reflecting body, having been heated or cooled internally, will have less effect on another body placed at any distance (in heating or cooling it) than a non-reflector would under the same conditions.

"All these conclusions have been verified experimentally, except that concerning the refraction of cold. This experiment remains to be made, and I am confident of the result, at least if the refraction of the heat is capable of being observed. This result is indicated in the 4th and 5th conclusions, which could in this way be submitted to a new test. It is hardly necessary to indicate in this place the precautions by means of which one would place himself beyond every kind of misobservation."

It is probably due to the fact that Pictet having performed an experiment (previously tried by Porta) upon the apparent radiation and concentration of cold by means of convex mirrors, which might be accounted for by assuming cold to be a principle susceptible to radiation, and to Provost's belief in the unsoundness of the above assumption which led him to his Theory of Exchange and, as has been seen, we are indebted to him for the first enunciation of the following very important facts in connection with the propagation of heat:

1st. That the radiations of a body are dependent only upon its own temperature without regard to the temperature of the surrounding objects.

2nd. That the character of the body and its surface modify its radiating and absorbing power.

3rd. That the tendencies of bodies of different temperatures is towards equality of temperature or equilibrium, but he assumed wrongly, as did Newton, that the speed with which this takes place varies directly as their difference in temperature.

For another important fact we are indebted to Sadi Carnot, who in his "Reflexions sur la Puissance Motrice du Feu," Paris, 1824, pointed out that "*The thermal motivity of a system cannot be increased by internal actions.*" A system in which all of the elements are at the same temperature has no thermal motivity, so that in an enclosure impervious to heat, when all of the bodies and the inclosure become of the same temperature, they will remain at the same temperature until some disturbing temperature is introduced. Provost's theory as well as the results of experiments all lead to a similar statement of the same fact, that if any number of bodies of varying temperatures are contained in an enclosure impervious to heat they will eventually become of practically the same temperature. He also considered heat to be a substance and its movements from a hotter to a colder body to be analagous to the movement of water from a higher to a lower level. Carnot also pointed out that heat cannot pass, unaided, from a colder to a hotter body, a proposition of great importance and which has since been the subject of elaborate mathematical demonstrations by both Kirchoff and Clausius.

Aside from the work of Carnot the first half of the 19th century was largely devoted to specializing upon the work of Provost. Leslie, studying by means of his differential thermometer, the effect of the surface of bodies as effecting radiation, showed that good reflectors were bad radiators and vice versa. Provostaye and Desains proved experimentally the existence of diffuse reflection of heat, in which the heat rays are scattered about in an irregular way from the surface of a substance in the same manner as light rays, and that the sum of the heat absorbed and reflected by a body approximated that radiated by black bodies. For instance, they found the radiation from polished silver to be 2.2% of a black body radiation, while that reflected from polished silver was 97% of a black body radiation, making the total heat radiated and reflected from polished silver equal to 99.2% of the black body radiation for that temperature, a result exceedingly close to the total value of 100%.

They also found that the sum of the reflected and radiated heat from glass was equal to 93.9% of the black body radiation and assumed that the difference was due to the diffuse reflection of heat above alluded to.

They also proved that the reflecting power of glass for heat increases very rapidly with the angle of incidence, and on the other hand that of polished metals increases very slowly.

Provostaye and Desains also did much to develop the Theory of Exchange by showing a general relation to exist between the radiating and absorbing powers of various substances. Their experiments, however, contained many anomalies due to the then unrecognized difference in the wave lengths of various radiations, so that we are largely indebted to Balfour Stewart for the first broad generalizations which have extended the theory of Provost to all kinds of radiations. In a series of papers communicated to the Royal Society of Edinburgh March 15, 1858, and April 18, 1859, and to the Philosophical Magazine for 1863, he throws much light upon this subject and especially are his researches upon glass important.

Stewart showed that the pencil of heat proceeding from a small surface of any object within an enclosure having an equal temperature was equal to that of a black body for that temperature, and that this held not only as to the total radiation but to every distinction of quality of which radiation is capable. It therefore follows that if two bodies are at the same temperature in such an enclosure, the radiation emitted by the one and absorbed by the other is equal to the radiation emitted by the second and absorbed by the first, not only in its heating effect, but in intensity, wave length, planes of polarization and every other variation of which radiation is capable, and the law that the radiation increases with the temperature must be true for every component part of the radiation when analyzed according to their wave length or planes of polarization.

When any radiation falls upon a body part of it is reflected, the balance enters the body and is either absorbed or transmitted. Lamp black absorbs nearly all the radiation falling upon it, reflects little and transmits none. Polished silver, on

the other hand, absorbs little, reflects nearly all and transmits none. Rock salt absorbs hardly any, reflects little and transmits nearly all. If these substances are placed in an enclosure having a uniform temperature, the pencil of radiations proceeding from the lamp black would be mostly radiated, that proceeding from the silver mostly reflected and that from the rock salt mostly transmitted radiations. It is obvious that from the surfaces of substances possessing these properties in various degrees the pencil of radiations is made up partly of radiated, partly reflected and partly transmitted radiations.

In considering the action of bodies imperfectly transparent to heat in an enclosure of equal temperature, Stewart was led to the following proposition: "In the interior of substances as well as in air or vacuo a stream of radiant heat is passing and repassing in all directions, and in the case of constant temperature, as this stream of heat passes any layer of particles, it is just as much diminished by the absorbing action of these particles as it is recruited by their radiation, so that the stream flows on virtually unchanged both as to quantity and quality until at last it reaches the surface."

This he proved by showing that thick plates of such substances as rock salt, mica and glass, radiated more heat than thin ones; he also proved experimentally the following facts with regard to glass:

1st. That glass is practically atherminous to heat of low temperature and long wave lengths; that for such heat it absorbs nearly all and transmits little.

2nd. That as the temperature increases and the wave length shortens, it becomes more and more diatherminous, absorbing proportionately less and transmitting proportionately more.

3rd. That up to the temperature of at least 700° C, the heating of the glass does not change its diatherminous properties.

This is admirably illustrated in the broken line curves,

Fig. 7, constructed from a table given by Melloni, showing the proportional radiations of a black body transmitted by glass plates of various thicknesses from .07 to 8 m. m.*

Assuming that the surface reflection is equal to 4% and the absorption equal to the radiation, the solid line curves, Fig. 7, for radiation of glass sheets at various temperatures and of various thicknesses was constructed, the ordinates representing the per cent of lamp black radiation radiated or passed and the abscissae the thickness of the plates.

From these curves it is readily seen that at 100° C. temperature of the radiant, glass plates over 1 m. m. thick stop, (reflect and absorb) all of the rays falling on them and have a radiating power of 96% of a black body, but as the temperature increases and the average wave length decreases they transmit more and more black body radiation and radiate less and less proportionately.

It will also be noticed that as the thickness increases the percentage of radiation increases, due to the internal radiation of the plate itself, so that as a plate approaches an infinite thickness it approaches the radiation of a black body. It will also be noticed that as the temperature of the radiant increases the percentage of black body radiation decreases, so notice that for glass sheets 8 m. m. thick the radiation is 96% of a black body at 100° C., 92.6% at 390° C., 78% at the temperature of incandescent platinum and 61.5% at the temperature of the Locatelli lamp.

When a body is heated it first begins to send out radiations of great wave length, and as its temperature increases radiations of higher frequency and shorter wave length are given out. Not only do these new radiations appear as the temperature of the body increases, but the intensity of all the

*A very homely illustration of these facts is to be found in the high temperature under glass surfaces exposed to the radiation of the sun, such as sky lights, hot beds and green houses. The radiations of the sun, being of short wave length pass readily through the glass envelope, but as the counter radiations are of extremely long wave length, they cannot pass the glass and the temperature of the enclosure is very sensibly raised.

radiations of a longer wave length increase so that a white hot body gives out more red radiation than a red hot body and more non-luminous radiation than a non-luminous body.*

As the total thermal value of the radiation at any stated

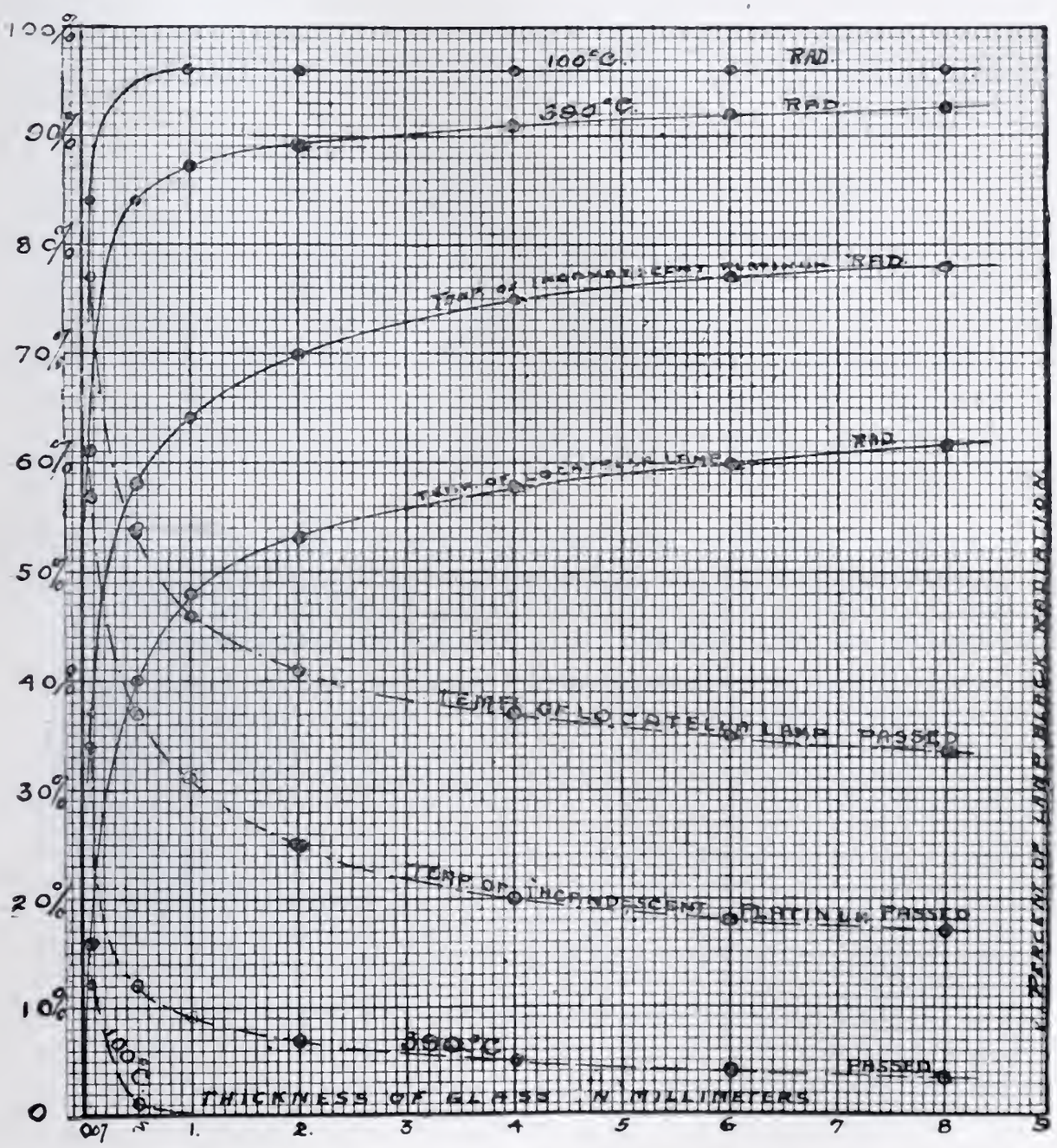


FIGURE 7.

temperature is equal to the sum of the thermal values of the various radiations for that temperature, it is evident that the

*This is known as Kirchoff's principle and has an important bearing on spectroscopy.

true law of cooling will not be a simple function of the excess of temperature as suggested by Newton and Provost.

Of the various formulae proposed up to the time of Dulong and Petit nothing need be said, as they have no value to the engineer. These philosophers, however, made a very successful and complete investigation of the rate of cooling of a large glass thermometer in both vacuo and while immersed in air and other gases.

The apparatus used by them consisted of a hollow spherical globe of thin copper blackened on the inside and arranged to be immersed in a liquid of known temperature. This globe was provided with an air tight cover through which the neck of a thermometer passed and in which an outlet was provided which could be connected to a gas bag, air or vacuum pump so as to permit of varying the character and pressure of the surrounding gas.

Having previously determined that the law of cooling of a liquid mass was independent of the character of the liquid or the form or size of the containing vessel, and using a thermometer with a large bulb holding some 3 pounds of mercury, they made a series of experiments, first with a plain glass bulb and afterwards with a silvered one.

Having heated the bulb of the thermometer, while carefully shielding the stem from heat, it was placed in the globe, the air or gas exhausted and the temperature of the enveloping liquid kept as constant as possible. The number of degrees that the mercury fell in successive minutes of time was then noted and the rate of cooling was assumed to be that for the average temperature of the thermometer during the time elapsed.

With the enclosure at various temperatures and the vacuum approximately 1 m. m. of mercury, they obtained the results shown in the following table; where t=the excess of temperature and θ the temperature of the enclosure:

Excess of Temperature of Thermometer	Velocity of cooling for various temperatures θ of enclosure.				
(t)	$\theta = 0°C$	$\theta = 20°C$	$\theta = 40°C$	$\theta = 60°C$	$\theta = 80°C$
240	10 69	12.40	14.35	.....	.....
220	8.81	10.41	11.98	.....	.....
200	7:40	8.58	10 01	11 64	13.45
180	6.10	7.04	8.20	9.55	11.05
160	4.89	5.67	6.61	7.68	8.95
140	3.88	4.57	5.32	6.14	7.19
120	3.02	3.56	4.15	4.84	5.64
100	2.30	2.74	3.16	3.68	4.29
80	1.74	1.99	2.30	2.75	3.18
60	.....	1.40	1 62	1.88	2.17

From these results Dulong and Petit deduced the law that the velocity of cooling of a thermometer in vacuo for a constant excess of temperature increases in a geometrical progression when the temperature of the enclosure increases in an arithmetical progression, and the ratio of this progression remains constant whatever be the excess of temperature.

By Provost's theory, if A, B and C=the absolute radiations of temperatures a, b. and c respectively.

A—B=rate of cooling of thermometer at temperature a in enclosure of temperature b.

B—C=rate of cooling of thermometer at temperature b in enclosure of temperature c.

A—C=rate of cooling of thermometer at temperature a in enclosure of temperature c.

then A—C=(A—B)+(B—C).

To test the preceding table by this assumption take for

instance $a=140°$, $b=80°$, $a-b$ or $t=60°$ and temperature of enclosure or $\theta=80°$; then by referring to the table we see that $A-B=2.17$. Also, for $b=80°$, $c=20°$, t or $(b-c)=60°$ and $\theta=20°$; and we see by referring to the table that $B-C=1.40$.

Also if $a=140°$, $c=20°$, t or $(a-c)=120°$ and $\theta=20°$; we see from the table that $A-C=3.56$, but as

$$A-C=(A-B)+(B-C), \text{ or } 2.17+1.40=3.57,$$

which is as close as could be expected.

Dulong and Petit assumed the function $F(t+\theta)-F(\theta)$ to represent the cooling of a thermometer in vacuo, where the first term denotes the absolute radiation of the thermometer at temperature $(t+\theta)$ and the second term the counter radiation of enclosure at temperature θ.

From these results they also developed the formula $R=M(1.0077^{\theta}+K)$ for the absolute radiation corresponding to the temperature θ on the centigrade scale, where R=total radiation and K a constant not yet determined, but which vanished in the formula for loss of heat by radiation which becomes

$$Q=M(1.0077^{t+\theta}-1.0077^{\theta})$$

where Q=loss of heat and M varies with the substance, being 2.037 for a naked thermometer and 0.357 for one with a silvered bulb.

While the laws of Dulong and Petit give excellent results when applied to the velocities of cooling of various substances, they are not so well adapted to the determination of their absolute measure of radiation. Wm. Hopkins, using as a unit the amount of heat required to raise 1000 grains of water 1° C, offers the following formula, where R represents the number of the above heat units lost in one minute by one square foot of a given surface in vacuo, θ represents as before the temperature of enclosure and t the temperature excess of the radiating body.

$$R=\mu\ 1.0077^{\theta}(1.0077^{t}-1).$$

The value of μ for this unit being given in the first column and for Therms per sq. c. m. per sec. in the second column of the following table:

	Values of μ when R=	
SUBSTANCES	1000 gr. 1°C Per Sq. Ft. Per Min.	Therms Per Sq. Cm. Per Sec.
Glass	9.566	.01112
Chalk (dry)	8.613	.01001
New red sandstone (dry)	8.377	.00974
Sandstone (building)	8.882	.01033
Limestone (polished)	9.106	.01059
" same block (unpolished)	12.808	.01489

From the above tables the effect of polishing the surface is plainly shown in the comparative values of μ for polished and rough limestone.

In 1879 M. Stefan, after carefully examining the work of various experimenters, proposed the formula $R=M_1\ (273+\theta)^4$ for the total radiation of a body at θ°C, so that the law of cooling would be $R-R_1=M_1[(273+t+\theta)^4-(273+\theta)^4]$ where R= radiation of a body at $(t+\theta)$°C and R_1=radiation of body at θ ° C, and M_1, a constant depending on the body. In 1884 Boltzman, speculating upon some ideas brought out by Bartoli, showed that the total radiation of a black body per unit of volume of the enclosure was proportional to the fourth power of its absolute temperature and pointed out that the law only applied to black body radiations. This law, which is known as the Stefan-Boltzman law, has been experimentally verified to the fusion point of platinum by Wilson and Gray, Lummer and Kurlbaum, Paschen and others, but in demonstrating this law corrections had to be made for the emissivity of platinum, the absolute value of which is problem-

atical. Wilson and Gray using for this ratio the values given in the following table:

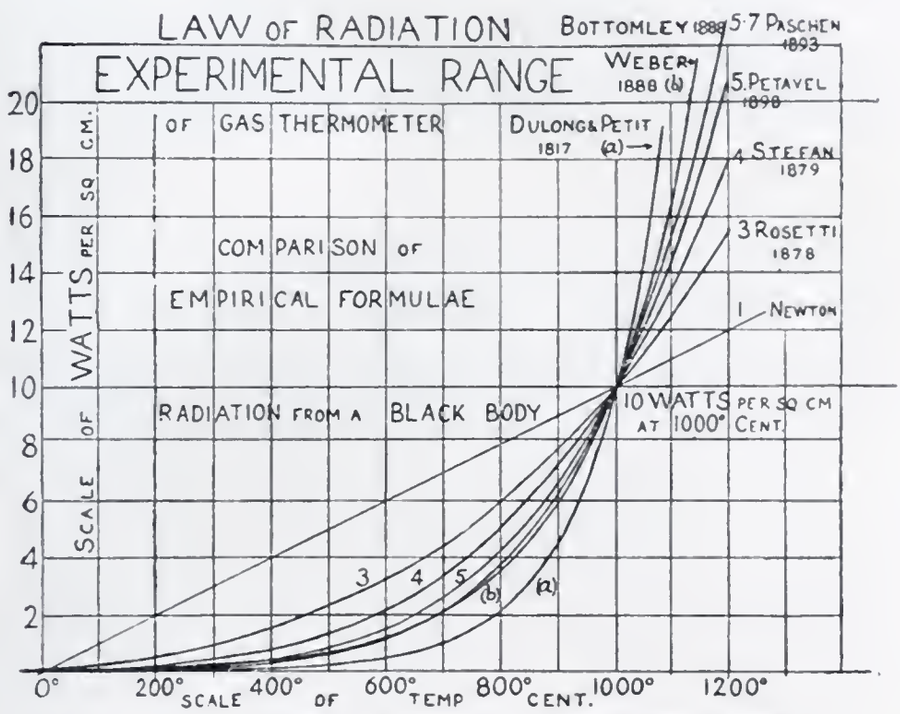
Temperature θ ° C	Emissive Power
300°C	1/5.4
600°	1/4.2
800°	1/3.9
1250°	1/2.9

It will be noticed that as the temperature increases the ratio decreases, showing that, for metals at least, the higher the temperature, the nearer the radiation approaches the black body radiation.

This fact has been so abundantly demonstrated by many investigators that we may safely say the radiations from all bodies atherminous (opaque to heat) increases more rapidly than those of a black body, while those diatherminous (transparent to heat) increase more rapidly the greater the thickness and at an infinite thickness they approach black body radiation.

Without going into further details of the various laws of radiation, a complete and full discussion of which will be found in The American Journal of Science, Vols. 138 and 144, I would like to call attention to a paper read by Prof. Callender before the Royal Society in March, 1899, in which he compares the work of various experimenters and the laws advanced by various theorists. In the paper he shows the strong family resemblance between the various laws of cooling when compared up to the limit of the experimental range, which he conceived to be 1000° C. By assuming the radiation of a square c. m. at this temperature to be 10 Watts per second, he made the curves for all the laws of radiation intersect at this point. These curves are here reproduced, Fig. 8, and

it will be noted that the curve No. 4, which is the Stefan or 4th power law, and which may be assumed to very accurately represent the black body radiation, diverges from and is considerably higher than the curve (a) which is for Dulong and Petit's law. Now, when you compare the characteristics of this curve with the data for radiation of glass taken from Melloni's table and plotted in the solid line curve Fig. 7, it will be seen that its general tendency is to follow very closely the path expected, so that for temperatures



Formulæ of radiation. Experimental range.

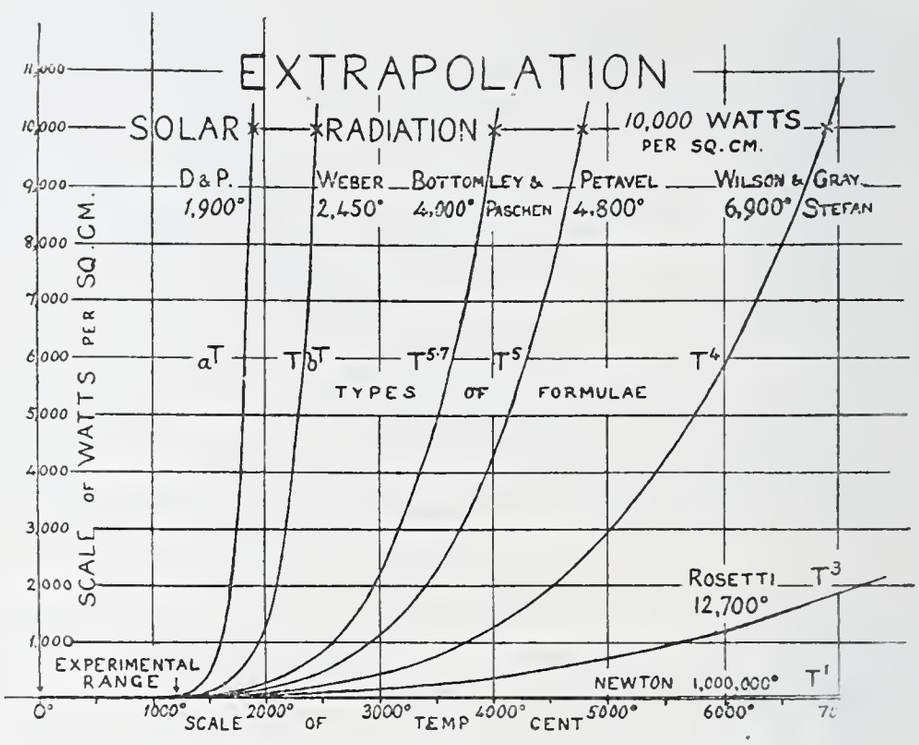
FIGURE 8.

at which glass is hard enough to retain its shape, temperatures during and after which annealing takes place, the laws of Dulong and Petit leave little to be desired. Some of the curves lying between these two would probably very accurately represent the radiations of such metals as iron and steel.

In another curve, Fig. 9, in which the experimental range of 1000° C is reduced to the thickness of a line, he shows the wide divergence where extrapolation is carried so far beyond the limits of actual experiment and the inherent characteristics of the laws are so diverse.

As the temperature at which annealing takes place, however, is only some 500° F higher than the limits of experimental verification of Dulong and Petit's law, it is not surprising that its application to this process should seem to so excellently meet the requirements.

Of the cooling action of radiation we know much in comparison with the cooling action of air and gases, these vary in so many ways that an accurate expression to represent their combined effect would be entirely too involved to be in any way useful. Dulong and Petit have, however, investigated this subject, and from the results of their experiments have enunciated the following empirical laws which express



Temperature of the sun by extrapolation.

FIGURE 9.

in a general way the relations between temperature excess and pressure, where similar conditions are to be compared, and may be stated as follows:

1st. The velocity of cooling due to the sole contact of a

body with a gas is entirely independent of the nature of the surface of the body.*

2nd. The velocity of cooling due solely to the contact of a body with gas is independent of the temperature of the body and is proportional to the excess of temperature in degrees C raised to the power of 1.233.

3rd. The cooling power of a certain gas depends not on its density, but on the pressure, P, of the gas.

For atmosphere the velocity varies as $P^{.45}$
" hydrogen " " " " $P^{.38}$
" CO_2 " " " " $P^{.517}$
" Olefiant gas " " " " $P^{.501}$

Combining these laws, the velocity, V, of cooling in gas may be written:

$V = Np^a t^{1.233}$.

Where N is a constant depending partly upon the dimensions and shape of the body and partly on the nature and volume of the gas; P the pressure of the gas expressed in millimeters of mercury; t the excess of temperature in degrees centigrade and a the exponent given in table below.

To reduce the cooling power of a gas to absolute units, let C denote the quantity of heat carried off by contact of a gas from one square foot of any surface in one minute at t°C above the surrounding gas of pressure P expressed in millimeters, then

$$C = .0372 \left(\frac{P}{720}\right)^a t^{1.233}.$$

Combining this with Dulong and Petit's formula,

$C = VP^a t^{1.233}$ in which the values for a and V are as follows:

*Leslie was the first to suggest the probability of this fact, but Dulong and Petit were the first to establish it by a series of exhaustive and careful experiments. They found, however, that the shape and size of the various members exerted a considerable influence in retarding or assisting convection currents. That the conduction or passage of heat literally through the gas was an appreciable factor and varied according to the heat conductivity of the gas and the distance the heat had to travel in the same way as conduction in solids, so that where the quantity of the enveloping gas is small the conductivity of the gas must be considered.

Gas	a	Value of V when C =	
		1 000 grams 1°C Per Sq. Ft. per min.	Therms Per Sq c. m. Per sec.
Atmospheric air	.45	.001926	2.239×10^6
Hydrogen	.38	.010571	12.289×10^6
Carbonic Acid	.517	.001196	1.391×10^6
Olefiant Gas	.501	.001841	2.139×10^6

From these tables and the respective values of a and V it will be noticed what a comparatively high capacity hydrogen has for dissipating heat. This is also shown in the annexed curves of Peteval, Fig. 10, giving the emissivity of a platinum surface in various gases, in which the emissivity of the surface may be stated to be the quantity of energy given off by a surface of 1 sq. c. m. in one second per degree centigrade of temperature difference between the surface and surrounding bodies.

The data for these curves was obtained by heating by electricity a platinum wire immersed in various gases, and when a state of equilibrium was reached the current strength and voltage were carefully noted. From this data the energy consumed was calculated and as the temperature remained stationary this energy would represent the heat dissipation of the wire, while from the resistance of the wire, which is easily calculated from Ohm's Law, the temperature was readily and accurately obtained.*

In regard to the dissipation of heat by conduction, this phenomenon has been carefully studied by all investigators of

*The method employed being that used in platinum resistance pyrometers, an excellent paper on which will be found in Vol. XX, No. 8, Sept., 1904. Proceedings of the Engineer's Society of Western Pennsylvania.

heat, and various formulae devised to express the laws governing the same. For the purpose of the present paper it is only necessary to note that heat passes through all solids from a higher to a lower temperature, the quantity passing through a unit area varying directly as the difference in temperature and conductivity and inversely as the distance traveled. The quantity of heat that will pass through a cube 1 c. m. square

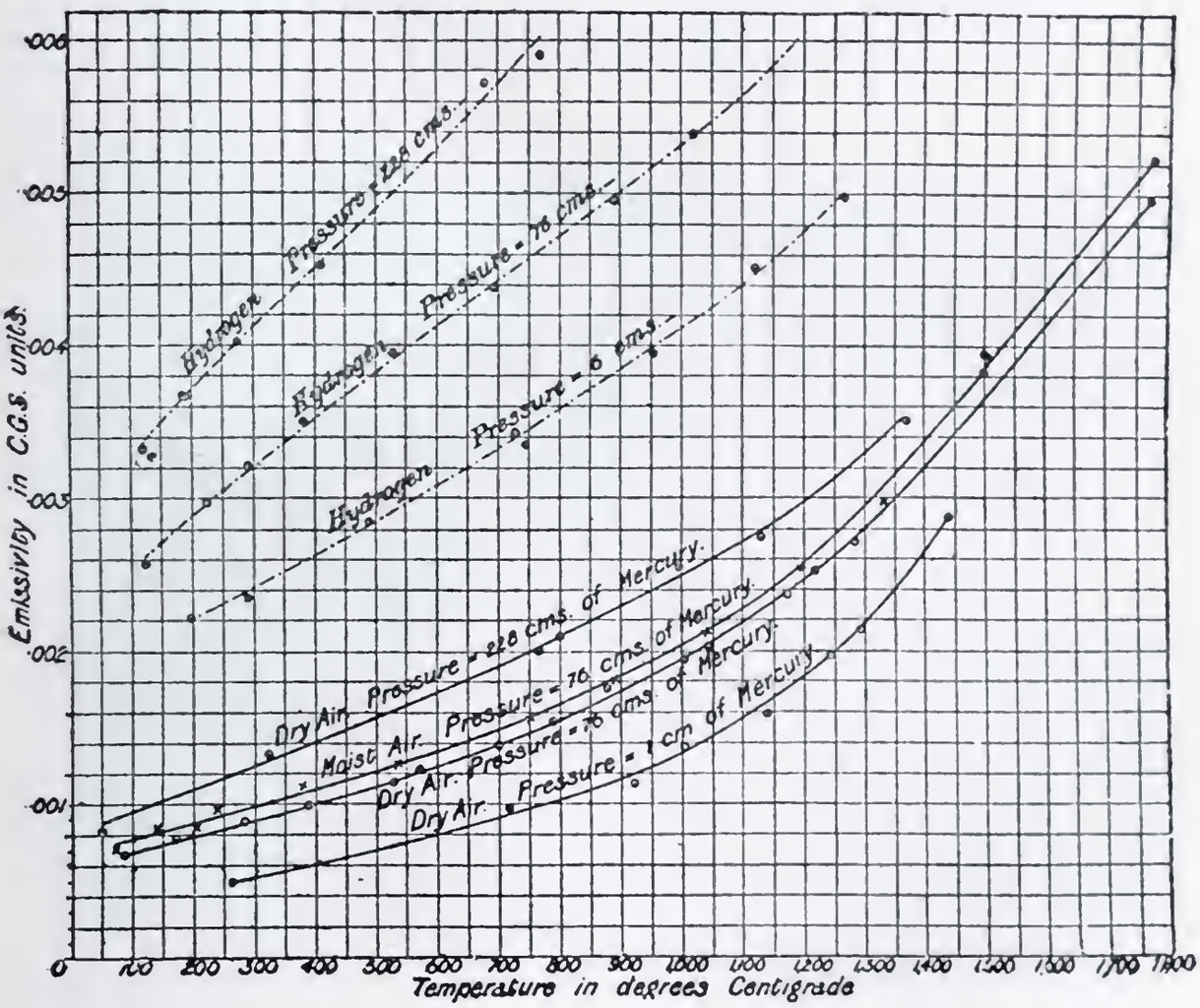


FIGURE 10.

divided by the difference in temperature between its hot and cold face is its co-efficient of conductivity, this conductivity varying according to the temperature of the substance. Prof. Tait has given reason to believe that in metals it varies approximately inversely as the absolute temperature; for non-metals, such as glass and brick, it varys approximately directly as the absolute temperature; for gases it varies as the square of

the temperature, inversely as the pressure and directly as the mass of the gas.

The conductivity, therefore, of a gas is practically independent of its pressure, unless it becomes so small that the mean free parts of the molecules are comparable with the dimensions of the containing vessel, when the conductivity rapidly decreases toward zero as a perfect vacuum is approached.

While these relations may simply express the general tendency of heat to modify the coefficient of conductivity, if

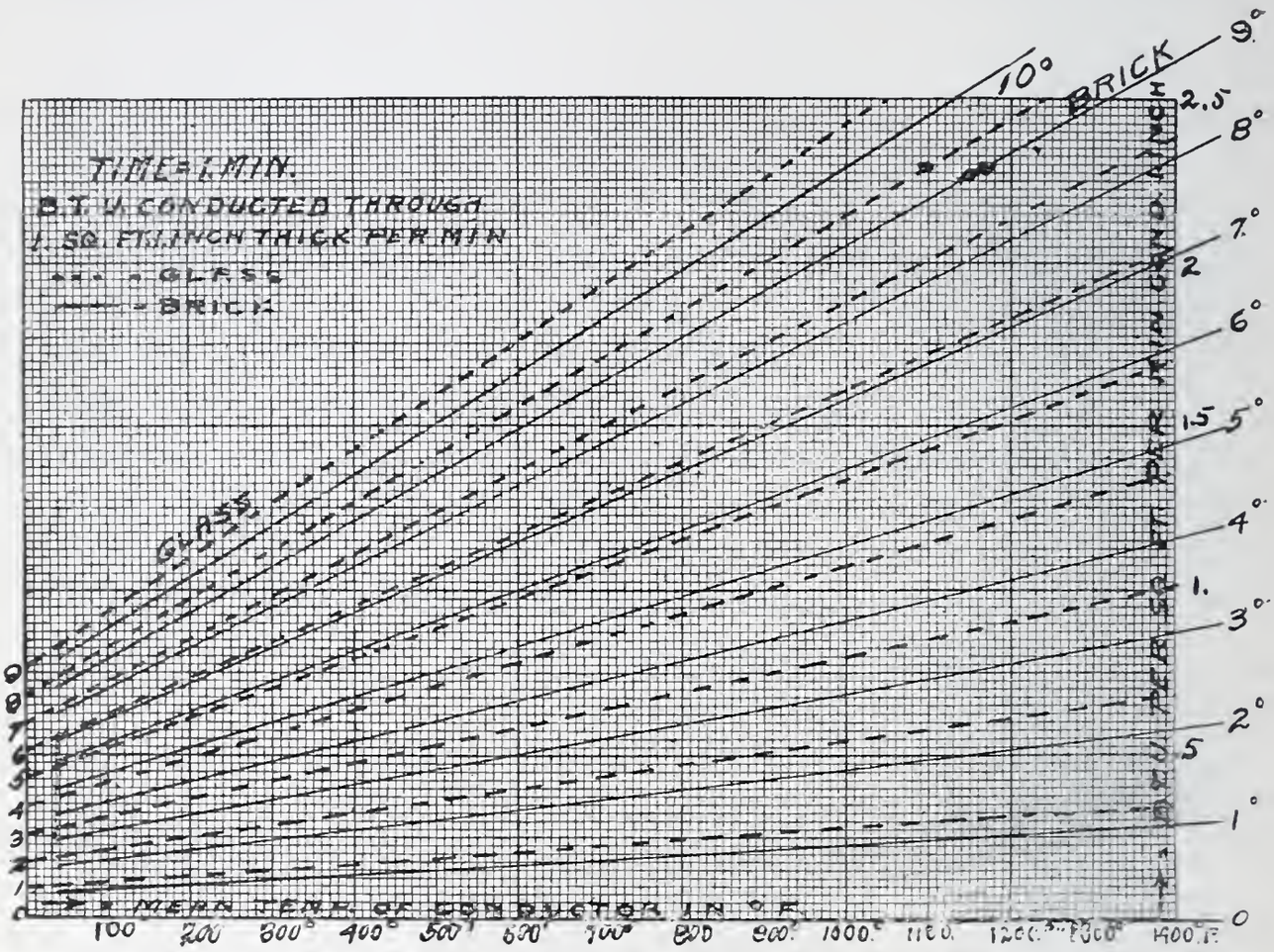


FIGURE 11.

corrections are made in accordance with these empirical laws the results will be found to be eminently satisfactory from an engineering standpoint.

Assuming the accuracy of this assumption, the series of curves shown in Fig. 11, were calculated and plotted. The solid lines represent the various differences in temperature, indicated at their ends in degrees F, between two isothermal

surfaces 1 inch apart in a brick wall hotter on one side than on the other. The dotted lines represent the same for a glass plate. The ordinates represent the B. T. U. of heat conducted per minute through one square foot of surface between the isothermal surfaces alluded to above. The abscissae represent the average temperature of the solid under consideration.

The method of using these curves will be readily understood from the following example: Take a brick wall 10 inches thick, temperature of the inside=1600°F, of the outside=600° F; the mean temperature would be 1100°F and the difference in temperature would be 1000°F.

Following up the ordinate at 1100° until it intersects the solid line marked 10°, then following the abscissa that they intersect, we find that each 10° difference in temperature would conduct 2.45 B. T. U. through one square foot of brick a distance of 1 inch or 1000° would conduct 24.5 B. T. U. through one square foot of brick a distance of 10 inches of wall the average temperature of which is 1100°F.

It will be remembered that Dulong and Petit in making their experiments used a glass thermometer enclosed in a cooled copper globe, and that in this regard the cooling action in their experiments was very similar to that which takes place in an annealing oven, for while the temperature of these experiments was considerably less than that at which annealing takes place, it is reasonably to be supposed that their law might meet these conditions. From their formula, therefore, the curves in Fig. 12 were calculated and their accuracy tested by constructing an electrical furnace having a graduated carbon core surrounded by a layer of carborundum one inch thick, this in turn being surrounded by 13 inches of steel fire brick. Three tubes were inserted in the furnace, one 13 inches from each end and one in the middle, in such a manner that they just touched the core and allowed thermometers to be introduced to measure its temperature, which was taken to be the average of the three thermometers. The temperatures up to 500°F were taken with standard mercury thermometers, those above with a Le Chatelier pyrometer.

The current was then turned on the furnace and kept at a constant quantity of one kilowatt until the temperature of the core remained constant for three consecutive hours, when the heat generated in the core could be assumed to be conducted through the walls and dissipated into the surrounding air.

The temperatures of the three thermometers were then noted and the current increased to two kilowatts until equilibrium was again established and the temperatures read. This was continued, the energy each time being increased by one kilowatt until ten kilowatts were being used and a core temperature of 2000°F was reached. The steps were then reversed dropping off one kilowatt at a time, readings of temperature being taken each time when equilibrium was reached.

From the mean of the ascending and descending readings a curve of heat dissipation was plotted over a curve of cooling already calculated for the furnace experimented upon. The experimental curve thus plotted crossed and recrossed the calculated curve in several places. The greatest deviation from the calculated result was less than 7% and could easily be accounted for from the fact that the experiment was conducted in one end of a casting hall where, when the wind blew from the hall, the air about the experiment was hot and dissipated less heat than when the circulation was in the opposite direction and cool air surrounded the furnace. If the curve had been plotted between the experimental readings so as to have a regular form it would have been similar to the calculated one, but on the average the ordinates representing energy dissipated in the experiment would have been longer than those calculated, showing possibly a maximum difference at the highest temperature of 5%, which could also be easily accounted for by the fact that in the calculations in question no correction was made for the increased conductivity due to increased temperature. The experiment, however, proved beyond the possibility of a doubt the usefulness of the curves here given. Curve 1, Fig. 12, represents the amount of heat lost in one minute of time by one square foot of glass surface

in contact with the air under the various conditions of temperature. Curve No. 2 represents the amount of heat radiated or absorbed in one minute of time by one square foot of surface of glass under various conditions of temperature. Curve No. 3 the amount of heat lost or absorbed in one minute of time by a square foot of surface of brick under various conditions of temperature. The ordinates represent B. T. U. of

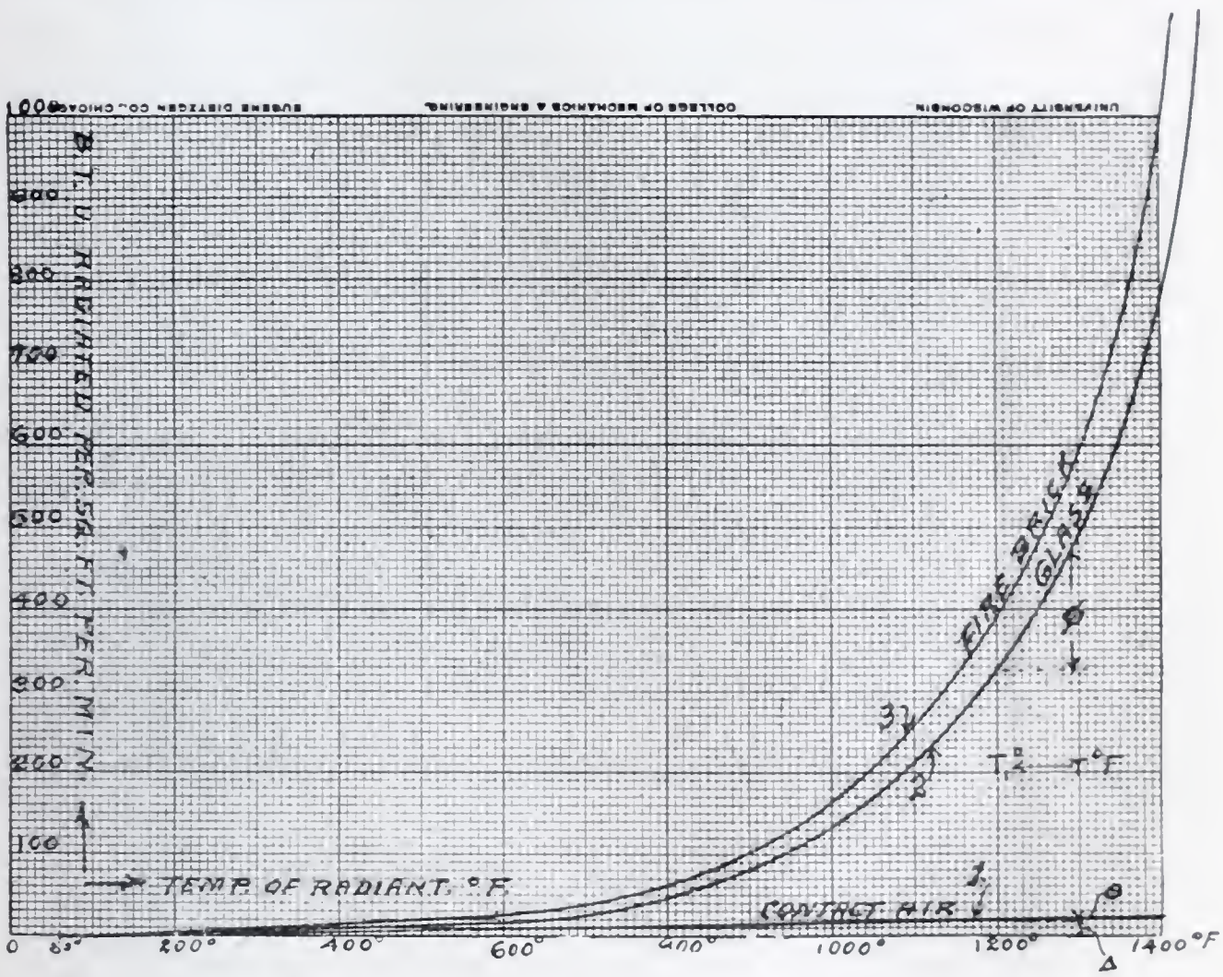


FIGURE 12.

heat lost or absorbed by a square foot of surface in one minute of time. The abscissae represent the temperature of the radiating, absorbing or conducting surface in degrees F.

As the point T is the temperature at which annealing begins, it will be readily seen that the amount of heat lost in a closed chamber by the glass in contact with the enclosed air is so small in comparison with the amount lost by radiation that it may be neglected and the problem considered as one entirely of radiation. If, however, draughts of cold air are admitted this cannot be done. For example: the temperature

of the glass being at T and the temperature of the oven being at T_1 the line ϕ would represent the heat lost by radiation;* the line θ the amount lost by contact with air, while the sum of the lines θ and $\triangle$ would equal the amount lost if cold air at 60°F were allowed to blow over the glass.

Fig. 1 is a closed kiln; 1 represents a sheet of glass resting on the hearth 2 and lying under a crown 3 having walls 4-4 opposed to the edges. Assuming that the surface of the glass 1 has a temperature T this heat will be radiated into the inner surface of 2, 3, 4-4, having a temperature T_1. From here it will be conducted through the material constituting the enveloping kiln 2, 3, 4-4 to its outer surface having a temperature T_2 from which surface it will be dissipated by radiation into the surrounding objects and by conduction and convection into the surrounding air.

Assuming the temperature of the surrounding objects and air to be 60° F, curve 4, Fig. 13, represents the tempera-

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*As all bodies at a temperature T_1 absorb from hotter bodies at temperature T the same amount of heat as they radiate at temperature T_1 the heat lost by a body in the enclosure is determined by the capacity to radiate and absorb of the weakest radiant. For instance, in the present case the glass at temperature T is radiating approximately 470 B. T. U. per minute more than at 60°F, all of which is absorbed by the fire brick arch whose capacity to absorb radiations of temperature T=600 B. T. U. more than at 60°F. Now the counter radiations of the fire brick at temperature T_1=400 B. T. U., but as the capacity of the glass to absorb these radiations is only 325 B. T. U. the balance of the fire brick radiations are reflected back or transmitted through the glass into the hearth. The general laws governing radiation from various substances having various capacities may be summed up as follows: Stewart has shown that where R represents the radiation of any particular wave length for a black body, aR may represent the amount absorbed by any other substance, as also the value of its radiation for that particular wave length. As the black body is a hypothetical body that absorbs all of the radiations that fall upon it, a must always be less than 1.

Kirchoff, carrying this a step farther, has shown that when r is the radiation of the same wave length as that above alluded to and falls upon a body, ar is absorbed and (1—a)r is transmitted, but as this is recruited by the radiation aR of the body itself, the total radiation proceeding from the substance becomes $(1-a)r+aR=r-a(r-R)$. Thus it will be seen that the value of the radiation proceeding from a substance is decreased only when $R<r$, which can only occur when the temperature of the radiating substance is higher than the absorbing one. Clausius has also shown that where the radiations proceeding from a body are concentrated by means of a convex mirror or burning glass upon a small surface the temperature of the surface can never be higher than the source of the radiations.

ture of the outside surface of walls 4-4 necessary to dissipate the various units of heat represented by abscissae from one square foot of surface in one minute of time.*

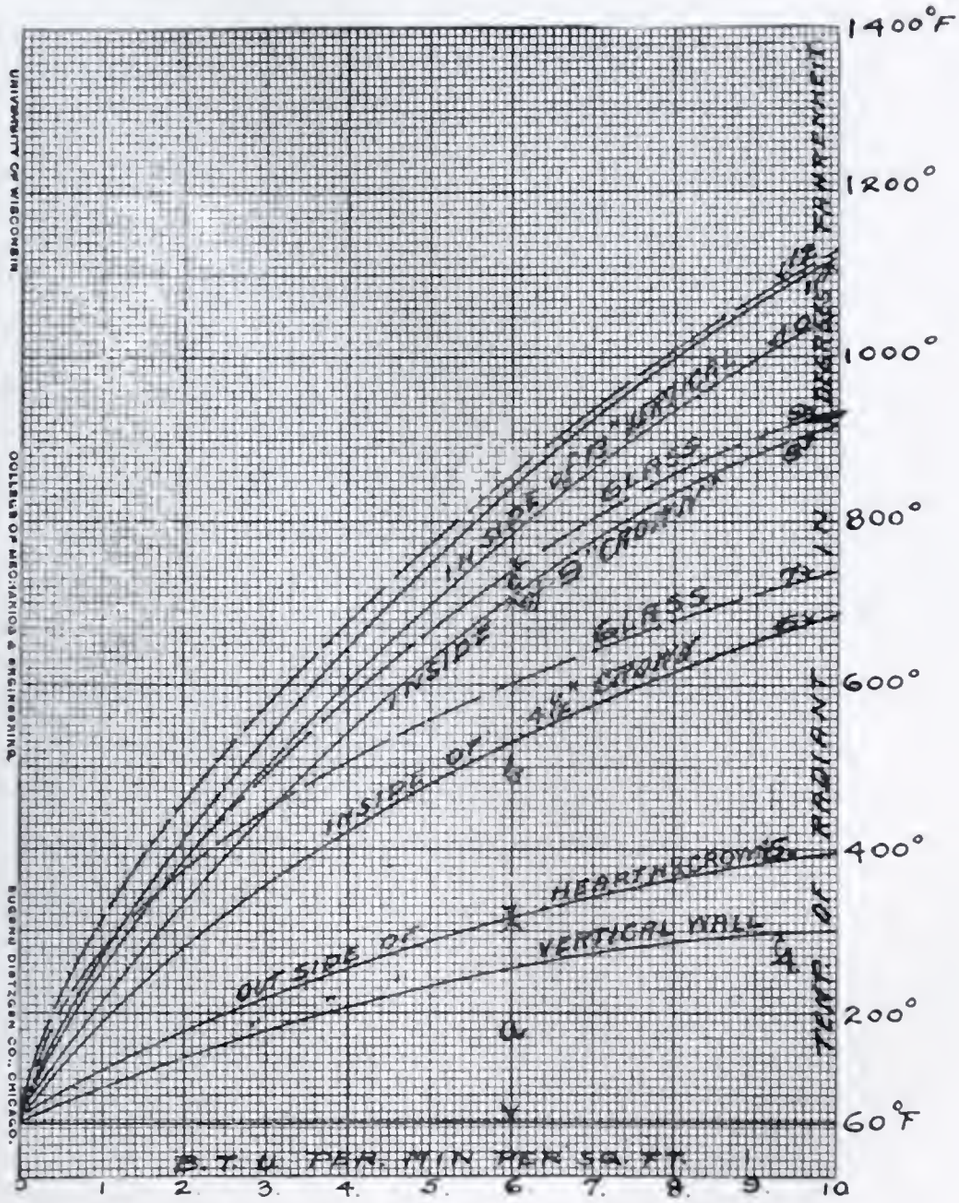

FIGURE 13.

That is to say, if the outside surface of the vertical wall is at any given temperature, by following the horizontal line corresponding to that temperature until it intersects the curve

*The value of a square foot of surface on a vertical wall to dissipate heat decreases as the height of the wall increases, being greatest at the bottom and least at the top. The calculations for this curve were based upon the mean value for walls of a height ordinarily found in kilns used for this purpose.

4, the length of this line represents the number of B. T. U. dissipated by one square foot of wall in one minute and can be read upon the axis of abscissa at the bottom. In like manner curve 5 represents the outside temperature of the hearth 2 or crown 3 necessary to dissipate corresponding amounts of heat in one minute of time. Curve 6 represents the inside temperature of such a crown 4½ inches thick. Curve 7 the temperature of the opposing surface of a sheet of glass under it. Curve 8 the inside temperature of a 9 inch crown. Curve 9 the temperature of the surface of the glass opposing the 9 inch crown. Curve 10 the inside temperature of a vertical 13 inch wall. Curve 11 the inside temperature of a 13 inch hearth or crown and curve 12 the temperature of the opposing surface of the glass under a 13 inch crown. These temperatures are calculated for a state of steady flow and assume that the temperatures remain constant for unit time.

A careful study of these curves makes the following facts apparent: 1st, the line (a) represents the difference in temperature between the air and the outside surface of a 9 inch crown necessary to dissipate 6 B. T. U. from each square foot of surface in one minute of time. 2nd, the line (b) represents the difference in temperature between the outer and inner surfaces of a 9 inch crown through which 6 B. T. U. are passing each minute. 3rd, the line (c) represents the difference in temperature between the glass and the inner surface of a 9 inch crown when each square foot of glass is losing energy at the rate of 6 B. T. U. per minute. 4th, that the difference in temperature between the outside and inside surface of the enveloping walls increases very rapidly as the temperature of the glass increases. 5th, that the difference in temperature between the glass and the surrounding envelope decreases as the temperature increases. 6th, that the heat insulation of the enveloping walls, therefore, constitute by far the most important element which serves to retard the cooling of the glass, so that if you had a straight arch over an annealing oven having a constant temperature throughout, the front half being 9 inches thick and the rear half 4½ inches thick, nearly

twice the heat would pass away through the rear half that would pass away through the front half.

Now as all of the heat must eventually be dissipated from the outside surface of the envelope the outside temperature of this surface determines, at least in one direction, the speed at which cooling takes place. It follows, therefore, that in a system of cooling sheets, where little or no heat is added aside from that to be eliminated and in which there is a uniform speed of cooling, the outer surface of the envelope should always have approximately the same temperature, and the thickness or insulating value of the envelope must be reduced in a regular manner as the temperature falls. The ideal system of cooling, therefore, would be an envelope having a regularly decreasing thickness with a uniform progression of the sheet of glass under it, but the conditions to be met in actual practice are so variable and the temperature at which the annealing begins to take place is so high as to render exceedingly difficult to construct, and complicated to operate, any apparatus which would successfully establish and maintain these conditions.

It is, therefore, customary to have the capacity for cooling of the insulating envelope greater than that actually required for the plates to be annealed, and to supply enough heat to the inner surface of the envelope to maintain an approximately constant temperature in each section, then to have a series of envelopes having progressively lower temperatures and to advance the cooling sheet at approximately regular intervals from a hotter to a cooler environment. The first st ge is accomplished in the series of ovens having plain hearths, upon which the glass rests and over which it is shoved to each succeeding position. This sudden movement from a hotter to a cooler environment, when the plate is advanced to a new position, produces in the cooling sheet a quenching action, and there is a violent exchange of heat between the hotter glass and the cooler surface of the envelope until they reach the temperatures corresponding to the normal conditions of cooling for that position of the glass, environment, etc. By

referring to Fig. 1, it will be seen that the portion of the inner surface indicated by heavy lines is opposed to the edge of the sheet, and as the mass of such surface is very great in proportion to the mass of crown surface opposed to an equal surface of glass in the center of the plate, the edge is chilled much more rapidly than the balance of the sheet, thereby

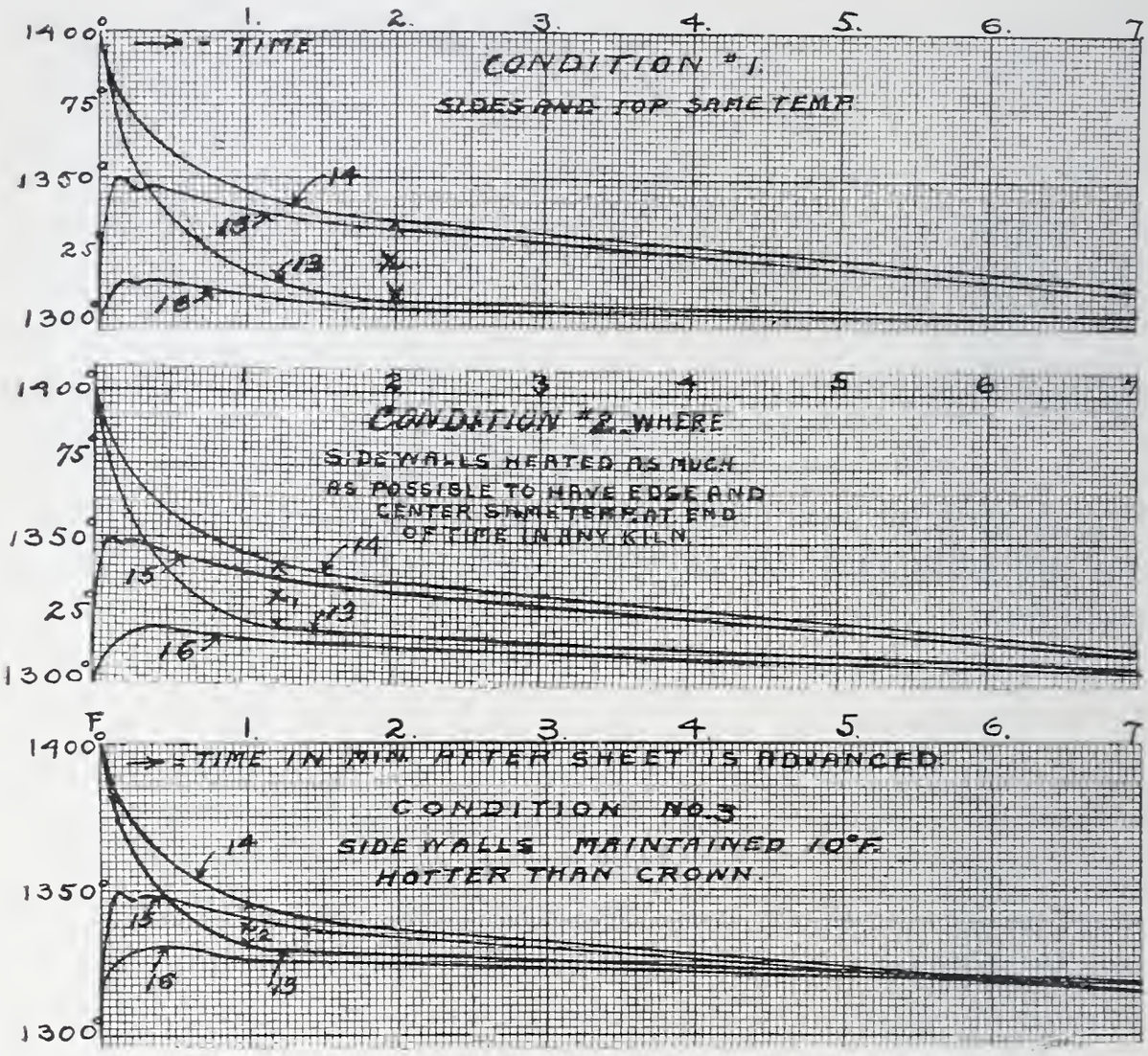

FIGURE 14.

throwing a stress in the edges sufficient to distort and bend the sheet or vent the edges.

In addition to this it will be noticed that the area indicated by the dotted line A, B, C, D, through which the heat is conducted away from the inner surface of the kiln opposed to the edge, is very great in comparison with that for the same

areas of glass in the center of the sheet as indicated by the dotted line E, F, also that the heat dissipating capacity of the outer surface of the vertical wall is much greater than for the corresponding area of glass under the crown. It will be noticed by reference to curve No. 4, Fig. 13, that the temperature of 300°F on a vertical wall will dissipate nearly twice as much energy as the same temperature on a horizontal surface; the reason being primarily that the heated vertical wall induces a strong draught of air across it while the horizontal ones are protected by a thin layer of heated air and convection currents move much more slowly over them.

In the old kiln arrangement several were built in banks having common walls between them, which in a measure corrected this difficulty, but even then the stress in the edges renders them so rotten that several inches have to be removed to make sure the strain is entirely relieved. In the ordinary leer arrangement, having a series of ovens, each one being maintained at an approximately constant temperature, but lower than the preceding one, and assuming the temperature of one to be 1300°F and that of the incoming glass 1400°F, conditions not actually existing in practice, but which would show the state of stress in the sheet somewhat greater than allowable,—we have condition No. 1 as shown in Fig. 14. Curve 13 represents the fall in temperature in the edge of the sheet. Curve 14 represents the fall in temperature in the body of the sheet. Curve 15 represents the rise in temperature in the surface of the crown opposed to the body of the sheet. Curve 16 the rise in temperature of the surface of the side walls opposed to the edge and the line x represents the maximum difference in temperature or stress between the edge and center of the sheet. The ordinates represent difference in temperature, the abscissae represent time after the sheet has been advanced.

In the systems of leer annealing heretofore in use the increments of heat required to balance the amount dissipated from the envelope and the amount lost therein by the glass

to maintain the proper temperature must necessarily be small if the system is to be economical. As the small flames of gas kept constantly burning for this purpose impinge on but a small surface of the envelope they produce a series of hot spots which modify this condition upon one or more sides of each oven in which they are placed. The successive steps in the movement of the sheet from one oven to the next, opposing the edges of each sheet alternately to a cold wall and one having hot spots, the edges are first cooled, then unevenly reheated and then cooled again in such a manner as to produce complicated and uneven strains which warp their shape and impair their quality. It has also been customary to so build these cooling chambers that the surfaces opposed to the edge are not symmetrical, thus little if any heat is dissipated through the bottom of the envelope, but almost all of it is forced out through the top or crown and sides. This necessitates a high speed of radiation from the upper surface of the sheet and maintains a considerable difference of temperature between the upper and lower surfaces during the entire time that annealing is taking place, so that when the temperatures eventually equalize, the unequal contraction resulting therefrom puts a strain upon the sheet which either bends or breaks it according to the condition of ductility in which it was when these temperatures equalized. It also leaves the surfaces in such a state of stress that when they are removed by grinding and the stress relieved, the sheets bend and curve in the same manner that castings are distorted when their scales are removed. It is to prevent this stress that the apparatus I am about to describe was designed.

If we have a sheet of considerable extent but very thin and hold it up in a vertical position so that it can radiate equally and freely on both sides no further provision is necessary. As the thickness increases, however, the radiating surface at the edge must be taken care of, and it would seem to be a self evident fact that if we were to oppose to these edges counter radiations equal in value to those emitted by the edge that the sheet would then cool in much the same manner

as a sheet without appreciable thickness, except that the heat not being at the physical surface of the sheet part at least must be conducted out. Therefore, the speed of radiation from the physical surface must be so controlled that the difference in temperature of the hotter interior and surface shall be as low as possible. It is, therefore, essential that the heat should be eliminated from both the top and bottom of the sheet, for in this case not only is the radiating surface doubled but the (distance) by (the quantity of heat to be conducted) is also reduced from 4 to 1 and as the speed of dissipation is also divided by two the resultant stress is reduced to ⅛ of what it would be were the plate cooled in the same length of time, entirely through the top. From curves No. 4 to 12, Fig. 13, we see that the control of the dissipation from the surface is easily accomplished by the proper adjustment of the thickness of the hearth and crown. But not so the control of the edges. In Fig. 14 we have the curves of cooling of the edge and of the center of the plate when the whole interior of the kiln is of an equal temperature as shown in condition 1 with the resultant stress represented by line x.

If we now heat continuously all of the side walls opposed to the edge of the sheet, and assuming that these side walls while heated as much as possible, to still have the temperature of the edge and center of the sheet equal at the end of the time the sheet remains in a given position, we have the condition plotted in the second series of curves as condition No. 2 with a resulting stress of x_1.

If we now heat continuously all of the side walls so that the edge will be 10° hotter than the center at the end of the time the sheet remains in a given position, we have condition 3 with a resultant stress first in tension on the edge and equal to x_2 and then in compression on the edge and equal to x_2. To overcome this stress I make use of the following arrangement:

Fig. 2 is a plan view of a series of ovens; Fig. 3 a section through these ovens on a line II—II showing plate A, hearth

2, crown 3 and side walls 4-4 in section. It will be noticed that the surface of the side walls 4-4, opposed to the edges of the sheet A and shown in heavy lines, are as short as possible and that they curve over these edges to meet the crown at the skewback. It will also be noticed that the crown consists of four parts, each springing from a side wall and joining each other in the manner of a hip roof, so that the surfaces opposed to each edge are all similar and as small as possible. While this is not absolutely necessary it is highly desirable. Around each wall are a series of openings in the hearth 2 having gas jets 12-12 introduced into them in such a manner that they form mixers and burners. Into the crown 3 is introduced a thimble 27 having on its upper end a damper 28 and openings in its lower end so placed as to allow the consumed gases to escape when the damper 28 is open, but prevent any heat from the glass under it radiating into the damper 28 when closed and also adapted to keep the burning gases within the oven until it shall be entirely filled.

The gas jets 12-12 are connected by a suitable pipe 13 to the valves controlling the gas supply located at or near the stowing hole 6 consisting of a valve and pipe 14 adjusted to furnish to the gas jets 12-12 enough gas to keep them all lighted.

Connected in a by-pass is a cock 15a and an automatic valve 18 which, when pulled, remains open for a pre-determined time the length of which is adjustable; it being the function of the valve to remain open part of the period elapsing from the time one sheet is removed until another is introduced.

The volume of gas which passes during this time is regulated by the cock 15a. The pipe 14a connects this main pipe to the diaphragm 30 controlling the damper 28. The action of this arrangement is as follows: After one sheet has been advanced from the oven the attendant pulls the valve 18 allowing the gas pressure to pass through the pipe 14a to the diaphragm 30 which raises the damper 28. It also allows a predetermined quantity of gas to pass through the cock 15a to the burner 12-12 filling the oven above with burning gas,

thereby evenly heating the entire inner surface of the oven above the temperature of the incoming sheet. After the lapse of the time during which the valve 15 is adjusted to remain open it closes, shutting off all of the gas except that which passes through the valve 14. The pressure falling, the flame recedes to the tips of pipes 12, 12, the diaphragm relaxes and the damper closes preventing any draughts within the oven. The flames having left the oven the surfaces equalize in temperature through the action of radiation, after which the next sheet is advanced into the oven and the whole allowed to cool until the time to advance the plate into the next cooler oven, when the process is repeated.

By this arrangement, while the temperature of the surface of the entire oven is uniform, the depth to which the surface is heated is greater at the curved surface opposed to the edge of the sheet, and by varying the thickness of these side walls the dissipation through them can be controlled so as to eliminate entirely the strains in the edges.

In this manner the inner surfaces of the successive ovens or kilns are alternately heated and cooled between two predetermined temperatures, this being easily regulated by increasing or decreasing the ratio of time the valve 18 remains open to the time it remains closed, or by adjusting the volume of gas passing through the cock 15a.

By modifying the insulating character or thickness of the hearth 2 or crown 3 the kilns can be so constructed as to maintain the upper or lower surface of the glass at the higher temperature, or keep them both equal, which is the ideal condition, this depending entirely upon the respective capacities of the crown and hearth to dissipate heat from their inner surfaces. When once they are properly proportioned they are practically independent of the irregularities of operation.

The openings in these kilns through which the stowing tools are introduced are provided in the following way: A jack arch which forms the skewback also forms the top of the stowing hole. A hollow tile 5 is mounted upon hydraulic cylinders 8 and 9 in such a way that when it is in the lowest

position it forms the bottom of the hole and when raised up it presses against the bottom of the jack arch. In this manner the hole is effectually closed and a heated surface opposed to the edge which preserves the symmetrical shape and character of the interior surface of the kiln. Similar arrangements might be used to close the passage ways between the ovens, but are not ordinarily necessary.

After the plate has been passed through a sufficient number of ovens and cooled to a point where it is sufficiently rigid, it is loaded onto mechanically operated supports which move it from the hot end to the cool end of a long chamber by which time it is cool enough to handle. Heretofore these chambers have been made of brick having two long and rather high vertical walls with iron doors at regular intervals forming the sides. A long arch or series of arches covers the top and a flue or series of flues form the bottom through which hot gases pass to heat the runway.

This construction offers the following disadvantages:

First: The weight of such an arrangement is very great, and requires a large quantity of heat to bring it up to a working temperature.

Second: The expansion of the long brick walls cannot easily be allowed for. When heated they exert a crushing strain upon themselves, rapidly getting out of line and cracking, thus letting in currents of cold air. As they are alternately heated and cooled they rapidly deteriorate, to minimize which they are heated extremely slowly, thus requiring a large expenditure of fuel.

Third: The products of combustion, containing considerable water, condense upon the cold surface of the brick and are absorbed by them and have subsequently to be driven off.

Fourth: The large side walls with the series of cold doors cool the edges very rapidly, and as the heat not so dissipated has to be eliminated through the crown, the strains in the glass, due to the difference of temperature in the various sur-

faces and sections, are greatly increased, as the strains are all in one direction, tending to bend or break the plate, its straightness or size is impaired.

Fifth: As the circulation of heat in the various heating systems is induced by stacks any cracking of the brick work is followed by an influx of cold air, besides, the circulation is greatly influenced by meteorological conditions, the direction and intensity of the wind, the opening of a door, the humidity of the air, etc.

Sixth: In all runways employing stationary and movable rods the glass is loaded onto the movable rods by means of an elevator which receives the sheet from the kilns and by elevating or lowering places it upon the ends of the movable rods. The top of this elevator being movable it is a difficult matter to keep the planes of the kiln bottoms, elevator and rods parallel.

Seventh: As the movable rods are moved back and forth from the cold end, and the hot ends are within the runway, the strains in the rods are first in tension and then in compression, so that if anything gets back of the rods they are buckled, or if they accidentally get unduly heated they are bent, greatly interfering with their operation.

Eighth: As the movable and stationary rods are usually supported upon separate members, any settling of either, or of their supports, throws the planes of the movable and stationary rods out of parallel, thus the glass is often supported only on its extreme edges and a broken sheet results.

Ninth: As none of the heat is eliminated by radiation through the bottom, the runways are necessarily very long and cumbersome to operate.

All of these difficulties may be overcome in the following manner:

The runway is constructed of metal with two triangular chambers running its entire length on each side of the main chamber in which the carrying apparatus is located. This metal runway is firmly secured at the hot end to suitable foundations, the rest of it being supported upon a series of rollers

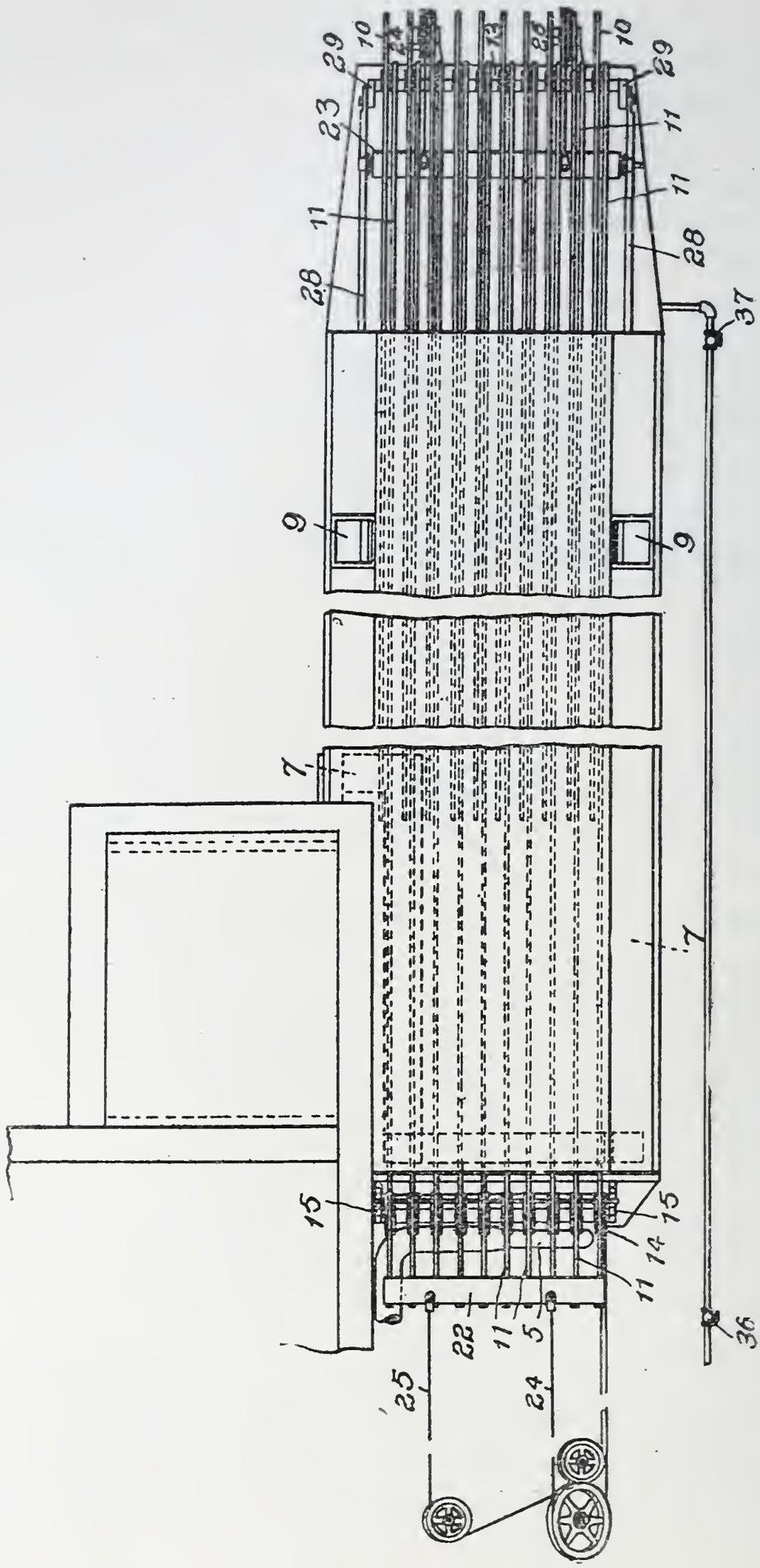

FIGURE 15.

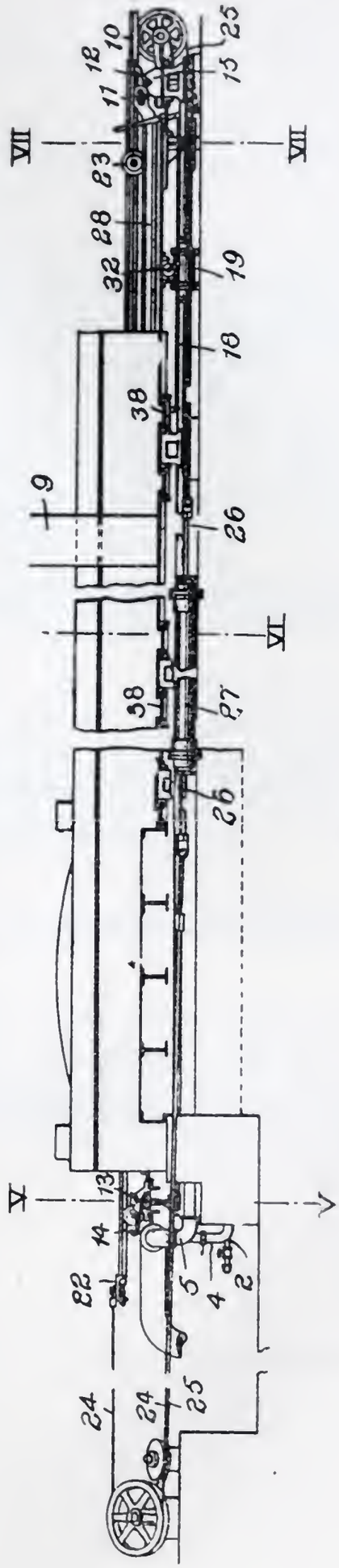
VII
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FIGURE 16.

moving on top of brick piers in such a manner that the runway can come and go, according to its temperature, without strain.

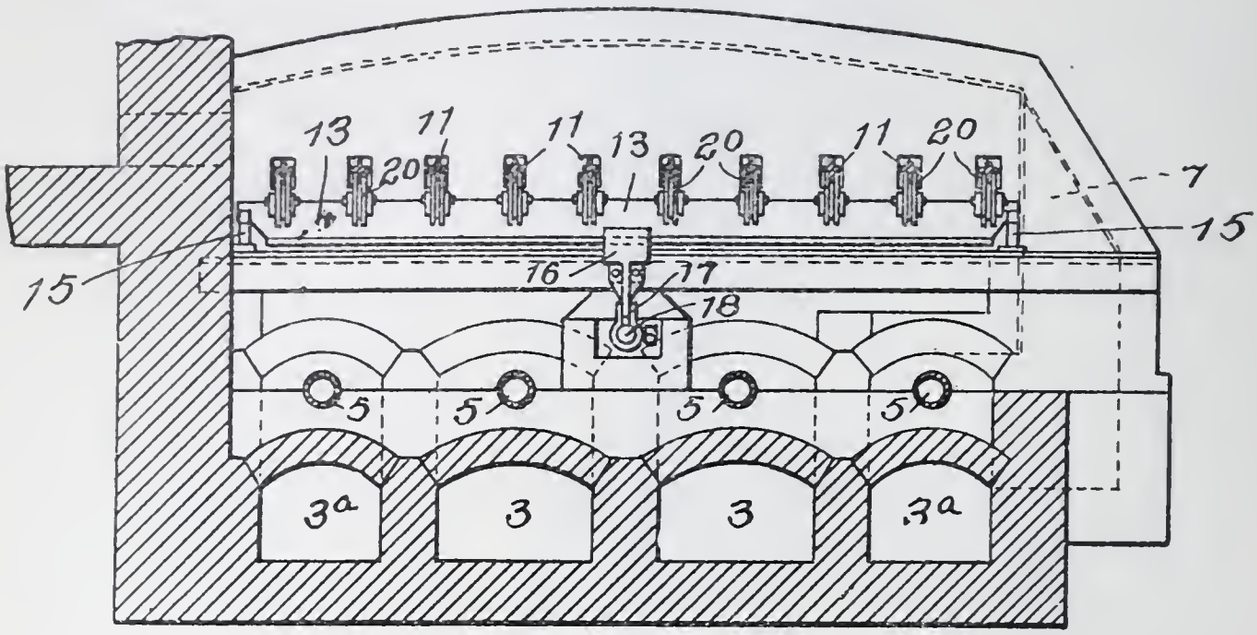

FIGURE 17.

The surface of this metal runway is covered with a light, non-conducting cover, such as magnesia, mineral wool or asbestos, being thick on the hot end and gradually reduced

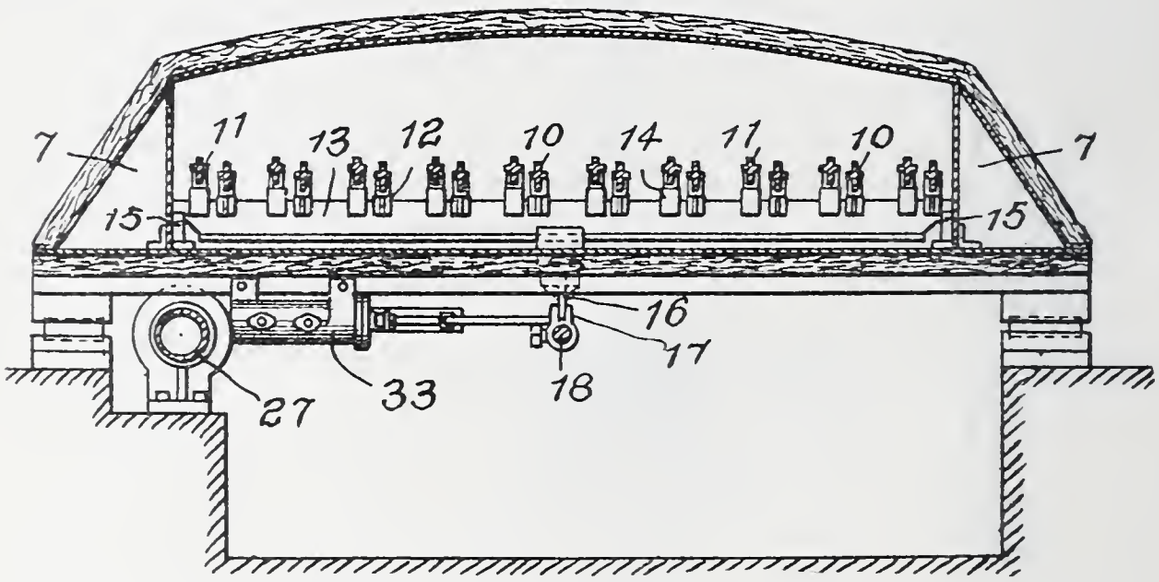

FIGURE 18.

in thickness to the cold end so that the speed of cooling shall be constant throughout its entire length.

The under side of the runway, being exposed to the free circulation of air, the heat is dissipated from the under surface of the glass as well as from the top, thereby doubling the effective radiating surface of glass and allowing of a shorter runway, or reducing the strain of the glass proportionately.

The construction of the runway and apparatus for advancing the plates through it will be readily understood from a careful study of the drawings. Fig. 15 is a top view and Fig. 16 a side view of the runway. Figs. 4 and 6 are vertical sections through the runway. Figs. 17, 18 and 19 are transverse

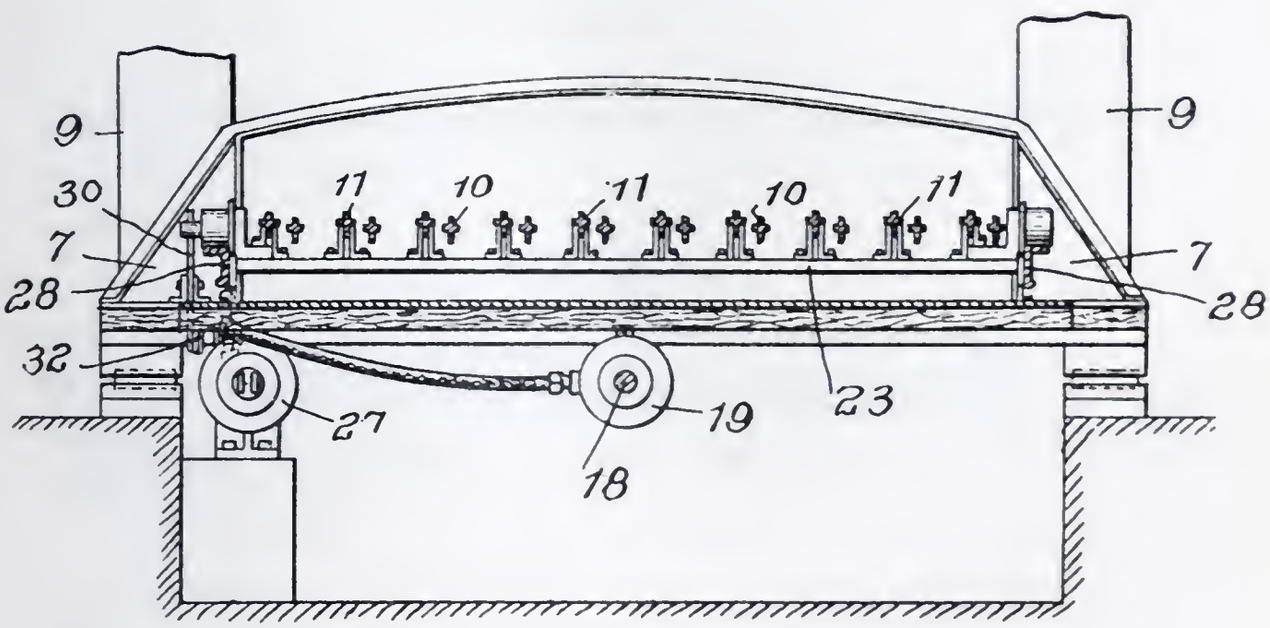

FIGURE 19.

sections through the runway on lines V-V, VI-VI and VII-VII, respectively. Fig. 5 is an enlarged view of the discharging end with the envelope partially cut away. Fig. 20 is a view of the cylinder which moves the rods 11—11, showing the controlling valve and its connection to the member 18.

The last kiln, or oven proper, is located at one side of the hot end of the runway, but there is an intermediate station in the hot end of the runway consisting of the hearth having slots cut wide enough to allow the movable rods to pass through them and deep enough to permit of their being lowered some distance below its surface. One end of the runway 41 projects

over this hearth and is closed by the plating 42. The runway 43-43 is preferably made of sheet steel with an arched top and two triangular ducts 7-7 running along each side. This metal runway is supported upon rollers 45 in such a manner as to allow the metal to expand without straining or getting out of line and is covered with a heat insulating cover 46-46, thick on the hot end and gradually reduced in thickness to the cold end.

Passing through the runway are two series of rods, 10-10-10 and 11-11-11, both supported upon cast iron brackets, 12-12-12, and 14-14-14, which rest on tee irons 13-13-13. These tee irons have knife edges formed by the vertical leg of the tee,

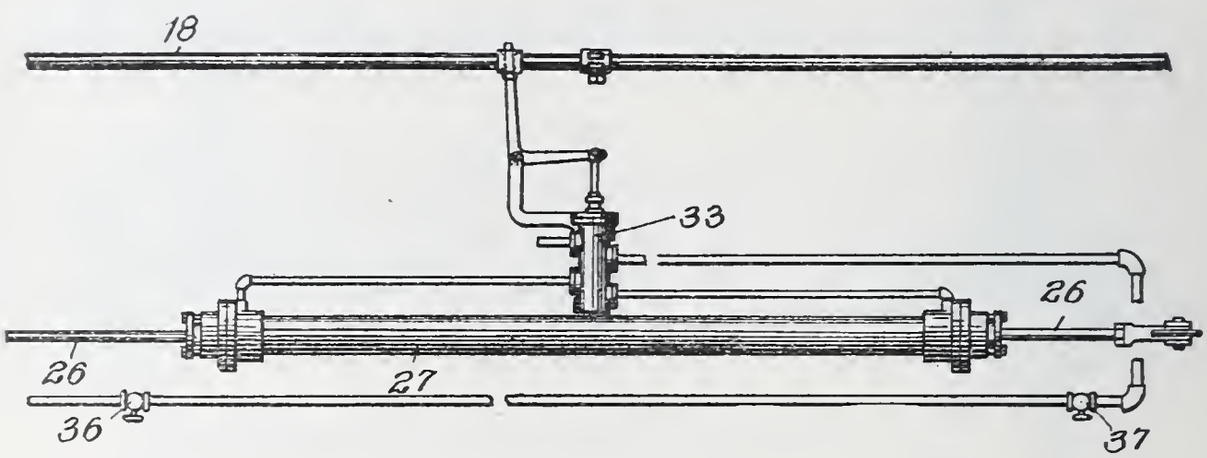

FIGURE 20.

resting in V-shaped saddles 15-15, which are supported by angle bars and saddles on the rollers 45-45. The rods 11-11-11 pass entirely through the runway and are mounted upon the rollers 20-20 which roll over the surface 21-21 of the brackets 14-14 in such a manner that the movements of these rods in either direction will tend to run the rollers down hill and facilitate the movement of the bars.

Depending from the middle of the tee iron 13-13 are controlling arms 16-16-16 which are actuated by means of the lugs 17-17 attached to the pipe 18. This pipe runs the entire length of the runway and passes through the cylinder 19, which is adjustably connected to the runway by the lugs 57 and 58 and serves to vibrate the pipe 18. The oscillation of

this pipe 18 working through the arms 16, tee iron 13, brackets 12-12 and 14-14, first raises rods 10-10 and depresses rods 11-11, and then raises rods 11-11 and depresses rods 10-10. In this way the sheet of glass will first be supported upon one set of rods and then upon the other.

At each end of the rods 11-11 are cross bars 22 and 23 to which the rods are connected, to 23 by means of angle irons and to 22 by means of adjustable eye-bolts, so that the tension in each rod can be equalized when hot. Attached to the cross-bars 23 and 22 are cables 24 and 25, which, running over the sheaves 63, 64, 65, 66, 67, 68, 69 and 70, connect with the cylinder 27. Turnbuckles allow the cables to be adjusted in length so as to keep them taut. This cylinder is moved by hydraulic pressure, the direction of movement being determined by the valve 33, which is an ordinary four-way valve. Valve 33 is controlled through the bell crank 77 and rod 78 by the pipe 18 in such a manner that when the rods 11-11 are up they will move from the hot end to the cold end, and when they are down they will move in the opposite direction.

The supply pipe to the cylinder 27 has valves 36 at the hot end and 37 at the cold end of the runway, so that by closing either one of them their movement may be stopped.

The cylinder 19, which actuates the oscillating pipe 18, is controlled by the four-way valve 32 operated through the crank 36, pitman 87 and levers 30 and 31. These levers are so placed that the cross-bar 33 will move them first in one direction and then in the other by the regular movement of 33 forward and back. Thus the movement of the bars 11-11 eventually cause the valve 32 to be reversed. This movement causes the pipe 18 to oscillate actuating the valve 33 which reverses the movement of the rods 11-11. Thus unless interrupted by the closing of the valves 36 and 37 in the main supply pipe to cylinder 27 the rods 11-11-11 would be first raised and then lowered and moved forward and back, automatically, always in the right direction.

It will be readily seen that by properly adjusting the sizes of openings into the various ends of cylinders the speed

of movement of the various parts can be controlled and the possibility of all shock removed. As the weight of the glass is always supported by the air pressure in either one end or the other of the cylinder 19, when this pressure is removed the glass descending tends to re-establish the pressure, so that when the supports are changed it is done with the greatest delicacy avoiding all strain due to shock.

At the cold end of the leer are placed two cutting tables 35-35, the tops of which are level with the rods 10-10 when in their lowest position. These tables run on the track 90-90 at right angles to the major axis of the runway, one table always being opposite to the ends of the rods. When the rods 11-11 are moving from the hot end to the cold end of the runway they will push off the plate resting upon the last section of the stationary rods 10-10 onto the table 35 immediately in front of them. In this way the glass is delivered upon the cutting table ready to be trimmed and carried away.

As these rods are automatically and slowly moved from one position to another there is ample time for the temperature to equalize in the rods, sheets and envelope, so that no strains occur due to the cold rods or from the rapid advance of the sheet to the colder part of the runway, all of which are important.

At the rear end of the runway and below the bottom are combination chambers 3-3 and 3a-3a, having suitable baffles to insure the perfect mixing and combustion of the gas and air which are introduced through the gas pipes 2 and the air pipes 4. These hot gases pass up into the phlenium chambers 6-6 where they are diluted with cold air introduced through the pipes 5a-5a and their temperature adjusted to suit the conditions required. From here they are conducted up into the runway, traverse its entire length and pass out at the cold end. By regulating the initial temperature of these gases and their velocity through the runway, a uniformly decreasing temperature will be established throughout its entire length, the character of which will be entirely within the control of the operator. That is, with a stated initial temperature,

the higher the velocity of the gases the farther the heat will carry down the runway and the hotter will be the cold end. As the pressure within the runway is higher than the atmospheric pressure the movement therein will be positive and no cold air can come in through the various openings.

It will be noticed that the hearth is at the same level as the hearths in the ovens and that the rods 10 and 11 are also at the same level when they are both at the same elevation, so that when the rods 11-11 are depressed they lie below the top of the hearth and when they are raised they are above it. While these rods 11-11 are in their lowest position the sheet of glass is advanced to a position on the hearth over the rods 11, so that when the rods are raised to their highest position the sheet is supported thereon high enough above the hearth 11 to allow it to be advanced to its next position, when it is lowered and the rods drawn back again.

As the rods 11-11 pass entirely through the runway there is no chance for anything to get down behind them, they are easily gotten at to adjust and they are supported at regular intervals, leaving no overhanging ends. As the rods are always in tension and drawn taut there is no chance for them to buckle. It will also be noticed that the floor of the runway is built up of a series of panels 38-38-38 on the angles 38a-38a in such a way as to be easily and quickly removed, thereby allowing easy access to the rods 10 and 11, the brackets 12 and 14 and I beam 13.

A careful study of the arrangement of the tee iron 13, brackets 12 and 14 and support saddle 15 will disclose the extreme simplicity of the arrangement. The knife edges allowing the system to be operated without friction, the dead load would naturally tend to deflect the support at the middle, but this is corrected by the torsional deflection at the ends due to the transmitted strain from the arm 16 through tee iron 13 to brackets 12 and 14.

DISCUSSION.

WM. A. BOLE, Member—How many of these ovens do you have in a series?

H. K. HITCHCOCK—Five, six or seven, depending on the size and thickness of the glass.

WM. A. BOLE—At what temperature is the glass discharged from the ovens into the runway?

H. K. HITCHCOCK—At about 800°F. When it leaves the last oven it is thoroughly annealed. In the runway it is largely a question of cooling it without breaking. Of course you could probably so strain the edge of the glass as to give it a hard or rotten structure the same as you can harden a perfectly annealed piece of steel in drawing it.

Glass is in many ways a very peculiar material as it passes rapidly from a very fluid state through all degrees of viscosity and ductility to a rigid elastic solid. Below the temperature at which it is a molten plastic mass a change of temperature of 200° will increase its elastic limit ten fold. The method of aggregation of the molecules has a very considerable effect upon its tensile strength and elastic limit. In the language of the glass house the strength of the glass all lies in the skin. For this reason all blown tumblers after their edges have been ground so as to be straight and smooth have the edges melted in, thus giving to the thin edge a true skin and increasing its tensile strength enormously. The tensile strength of glass in thin sheets is about 6000 lbs. per square inch, in ½ inch bars 2500 lbs. per square inch.

Below the temperature of 800° the elastic limit of glass and point of rupture are very close together and if glass is subjected to great stress and sufficient time is given for the molecules to re-arrange themselves the glass will undoubtedly harden. In using the word annealed I use it in the sense of denoting the method of aggregation of the molecules which affects the hardening of the material. A plate that cuts readily with a diamond is said to be soft and well annealed. Such a plate may, however, be in a high state of stress like a per-

fectly annealed plate which is under mechanical stress near the yield point.

By regulating the area of the partition between the runway and the chamber in proportion to the crown and bottom you can easily control the difference in temperature between these side chambers and the runway proper. Originally these runways were made with brick arches and the thickness of the insulating envelope at the hot end was just the same as it was at the cold end. It is obvious that if you want to cool the glass at the hot end at the same speed as at the cool end you want a thicker envelope there. Calculating the insulating capacity of this envelope at the hot end so that it would just conduct away the amount of heat that should be conducted from the upper and lower surfaces of the glass, we would have to have a brick arch and hearth that would be approximately four feet thick, a condition that is absolutely impracticable, but using better insulators, four inches of such material as we now use would be equal to four feet of brick in insulating capacity.

I think the way most leers are built to-day, although the rough glass may be perfectly straight, when they grind it the stresses in the surface are removed and the sheet bends, but it is sufficiently straight so that when you glaze it in a window you force it into position and it is not commercially objectionable.

Wm. A. Bole—Is there space between the bottom of the plate and the bottom of the oven?

H. K. Hitchcock—Yes, there is space below the hearth of the ovens, also in the runway there is a great deal of space.

Wm. A. Bole—Do we understand that this long tunnel for cooling is a substitute for the zig-zag?

H. K. Hitchcock—No, they are used to reduce the temperature of the glass before it could stand the mechanical stress of being supported on a series of rods.

WM. A. BOLE—Then by the time the glass gets through the tunnel it is about the temperature of the air?

H. K. HITCHCOCK—It should be, but often, unfortunately, it is not. I have measured the temperature of glass coming out that was 212°F, but it was entirely too hot. I should say 150° would be hot enough, as hot as a man could handle with comfort.

WM. A. BOLE—What length of time is required to cool plate glass?

H. K. HITCHCOCK—In the old kiln operation it was a question of three days probably. With annealing ovens and a runway there would be probably from the time it went in one end to the time it came out at the other five hours.

WM. A. BOLE—I have had frequent experience of iron castings breaking from a cause quite similar to this. You get there a substance surrounded by sand on the outside and perhaps sand in the form of cores in the interior, sometimes of very complex structure. We have occasionally had experience of castings breaking long after being made, not from engineering stresses applied in the design but from internal stresses set up at the time the casting was going from red to black heat and from black heat to cold.

H. K. HITCHCOCK—I think that is largely the cause. I have seen a great many castings for large wheels that were very badly designed break at the hub. And the heavier they made the hubs, the more the wheels would break.

WM. A. BOLE—A casting could cool synchronously as this plate of glass is intended to, that would tend to excellence in the castings, but they hardly ever do that in any exact sense.

H. K. HITCHCOCK—Of course you could not control the radiation in the cooling of the casting in this way, that would be very difficult because the casting must set before you

could take it out of the sand. But in designing the casting to be of a uniform thickness as nearly as possible and having heat dissipating surfaces proportional to the heat content, these stresses would be very largely removed.

WM. A. BOLE—Yes, frequently parts of the casting not necessary to be strong ought to be made thicker in order to cool more synchronously with the other and heavier parts of the same casting.

H. K. HITCHCOCK—Emerson says: "Things themselves refuse to be mismanaged." This is especially true of glass and I presume as much money has been spent in perfecting methods for annealing glass as in any other branch of the art.

*TESTS AND THEORIES IN THEIR RELATION TO SPECIFICATIONS FOR BRICKS.

†JOS. A. SHINN,
Member.

Brick: A molded block of clay, either burned or sun-dried; in the United States, usually about 8½ by 4¼ by 2 inches in size.

It is obviously impossible, from the above definition, to state in general terms the strength of such material so as to convey information of value to the engineer or architect. The engineering hand-books make a pretense of giving the strength of bricks of which the following are some examples.

Compression per square inch, soft, 450 to 600 lbs.

Compression per square inch, first-class machine pressed, 3112 to 6224 lbs.

Compression per square inch, kind not specified, 555 to 4168 lbs.

Compression per square inch, kind not specified, 5960 to 32,351 lbs.

The termination of these numbers in other than zero would indicate the intention of conveying exactness of statement. If a person consulted one of these he would suppose that he had obtained information of some value. If, perchance, he consulted all, he would realize how little information could be obtained from such statements. As well might they undertake to give the size of a piece of chalk in like brief manner.

A brick with a crushing strength of 500 lbs. per square inch, will support a column of approximately 300 feet in heighth of a material of like weight, and when in columns of one foot section, with good mortar, would support material of like weight of more than 400 feet in height before crushing the bottom brick. In England and in Europe bricks having a

†100 Broadway, New York.
*Meeting of Structural Section, Oct. 23, 1906.

crushing strength of 1000 lbs. per square inch, are considered suitable for all ordinary house construction.

In the Engineering News of April 13th, 1905, there was published a detailed report of tests of fourteen makes of "Hudson River common bricks" and two makes of "Philadelphia Pressed bricks," five bricks of each make being tested, made for the Building Department of Manhattan by Prof. Ira. H. Woolson, E.M., of Columbia University. This report contains the only reliable information on that subject which I have been able to obtain. A report which gives only the average of a number of bricks does not necessarily convey accurate information and may be absolutely misleading, as instance a series of compression tests giving 1607, 2436, 2767, 3579 and 5129, with an average of 3108 lbs. per square inch.; and a series of modulus of rupture with a minimum of 212 and a maximum of 1010 and an average of 687.*

In reading the report of Prof. Woolson my attention was particularly attracted to the compression tests of saturated bricks. It was assumed, and apparently proven, that saturation reduces the compressive strength of all such material, but in some instances it was found that it apparently gave an increase for which he gave the following explanation:

"Immediately after the specimens had been weighed for the five days of absorption, they were faced with plaster and crushed to ascertain the effect of saturation upon the strength; comparison being made with the other half of the same brick tested in its normal condition. Over 70% of the bricks showed a decrease in strength varying from 10 to 45%. The remainder reversed the proposition and gave an increase rather than a decrease in strength.

"The reason for this is uncertain, but probably may be attributed to the well-known fact that owing to presence of pebbles, small cavities or imperfect burning, one-half of a common clay brick is often much stronger than the other half. This is the only explanation which would account for the erratic results obtained."

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*MODULUS OF RUPTURE: The measure of the force required to break a substance across, as compared with the force required to break a bar of the substance one inch square.

In reading the table, however, I thought I could detect a sequence in these seeming irregularities and upon making an analysis by separating the different kinds of bricks, I found that all of the hard bricks and 26 of the medium bricks showed a reduction, while six of the medium and all of the pale showed an increase.

This finding did not agree with my previously conceived ideas on the subject, and I determined to make a further investigation, using as a basis of comparison the specifications for sand-lime and sand cement bricks which accompanied this report, and for the formation of which this series of tests was made.

Table 1 is the result of the tests in series as published, showing all of the points below specification in bold-faced type.*

*The specifications provide that bricks selected by an engineer of the department should be subjected to tests as follows:

7. The material must be subjected to the following tests: Transverse, Compression, Absorption, Freezing and Fire.

8. These tests shall be made in series of at least five, except that in the fire tests a series of two (four samples) is sufficient. The transverse tests shall be made first on full size samples (8 by 4 by 2). The resulting half samples are then used for the compression and absorption tests, but in no case must both halves of the same piece be used in either series. Half samples may also be used for the freezing and fire tests under the same restrictions. The remaining samples are kept in reserve, in case unusual flaws or exceptional or abnormal conditions make it necessary to discard certain of the tests. All the samples must be marked for identification and comparison.

9. The transverse test shall be made as follows: The sample shall be placed flatwise on two rounded knife-edge bearings set parallel, seven inches apart. A load is then applied on top, midway between the supports, and transmitted through a similar rounded edge, until the sample is ruptured. The modulus of rupture shall then be determined by multiplying the breaking load in pounds by twenty-one (three times the distance between supports in inches), and dividing the result by twice the product of the width (approximately 4) in inches by the square of the depth (approximately two) in inches.

.10 The Compression test shall be made as follows: The sample must first be thoroughly dried to a constant weight. It must be carefully measured, then bedded flatwise either in plaster of Paris or blotting paper, to secure a uniform bearing in the testing machine,

and crushed. The total breaking load is then divided by the area in compression in square inches.

11. The Absorption test must be made as follows: The sample is first thoroughly dried to a constant weight. The weight must be carefully recorded. It is then placed in a pan or tray of water, immersing it to a depth of not more than one-half inch. It is again carefully weighed at the following periods: Thirty minutes, four hours and forty-eight hours, respectively, from the time of immersion, being replaced in the water in each case as soon as the weight is taken. Its compressive strength, while still wet, is then determined at the end of the forty-eight hour period, in the manner specified in Regulation 10.

12. The Freezing test is made as follows: The sample is immersed , as described in Regulation 11, for at least four hours, and then weighed. It is then placed in a freezing mixture or a refrigerator, or otherwise subjected to a temperature of less than fifteen degrees Fahrenheit, for at least twelve hours. It is then removed and placed in water, where it must remain for at least one hour, the temperature of which is at least one hundred and fifty degrees Fahrenheit. This operation is repeated twenty times, after which the sample is again weighed while still wet from last thawing. Its crushing strength should then be determined, as called for in Regulation 10.

13. The Fire test must be made as follows: Two samples are placed in a cold gas furnace, in which the temperature is gradually raised to seventeen hundred degrees Fahrenheit in one hour. One of the samples is then plunged in cold water (about fifty to sixty degrees Fahrenheit), and results noted. The second sample is permitted to cool gradually in air, and the results noted.

14. The following requirements must be met to secure an acceptance of the materials: The modulus of rupture must average four hundred and fifty and must not fall below three hundred and fifty in any case. The ultimate compressive strength must average three thousand pounds per square inch and must not fall below twenty-five hundred in any case. The percentage of absorption (being the weight of water absorbed divided by the weight of the dry sample) must not average higher than fifteen per cent. and must not exceed twenty per cent. in any case. The reduction of compressive strength must not be more than thirty-three and one-third per cent., except that when the lower figure is still above three thousand pounds per square inch, the loss in strength may be neglected. The freezing and thawing process must not cause a loss in weight greater than ten per cent., nor a loss in strength of more than thirty-three and one third per cent., except that when the lower figure is still above three thousand pounds per square inch, the loss in strength may be neglected. The fire test must not cause the material to disintegrate. (NOTE.—No great stress will be laid on this last test.)

I found that eight of the eleven bricks showing increase after saturation would be rejected by the specifications because of giving less than 2,500 lbs. per square inch compression and that four of these eight showed modulus of rupture of less than 310 lbs. This would seem to warrant the theory that the increase was due to local causes. When, however, it was shown that of the thirty-two bricks giving reduction, twenty-four gave compressive strength of more than 3506 lbs. per square inch, the theory of local causes did not seem acceptable. The pale brick showing the greatest increase (19%) is the lowest in compression (1607 lbs. per square inch), and the medium brick showing the greatest increase (87.7%) is next to the lowest of its kind with a compressive strength of 2240 lbs. per square inch.

At this point I considered it of more importance to determine the rules which govern rather than the cause of the exceptions, and feeling confident that hard burned bricks were not reduced in compressive strength by saturation, my effort was directed to ascertain the truth of that theory.

Investigation and inquiry convinced me that the two ends of a soft mud pressed brick are seldom the same in density, and that more or less of the bricks in all kilns are not subject to the same temperature at both ends.

If the bricks were of unequal strength throughout, the two pieces of the brick broken under transverse strain would be of unequal size, and the break would generally occur on the side of the centre line in the direction of the weaker end of the brick. This introduced a new and important factor in the calculation.

General Q. A. Gilmore, in his report on building stones of the United States, shows that the compressive strength per square inch of such material increases with the increase of area.

As the number of pieces showing increase was but eleven out of a total of forty-three (approximately one-fourth), and nine out of the eleven were otherwise defective, it did not seem reasonable to suppose that the larger and stronger ends of these particular bricks should have been subjected to the tests of

saturated compression, and that the shorter and weaker ends of thirty-four bricks of better general characteristics should have been taken.

It was therefore necessary to assume that either because of some special reason, or from the operation of the personal equation, which produces uniform action without reason, the short end had invariably been subject to saturation. With the finding that of the forty-three bricks so tested, there were but three of which the end subjected to the saturation test was of greater area than the end subjected to dry compression, the reason for it was recalled.

I think that the investigation proves that good average clay bricks are not weakened in their compressive strength by saturation, and that the strengh of the weaker brick is not thereby increased.

Table II. are the bricks giving tests below specifications showing the failures in groups under each specification.

Table III. the bricks subjected to the saturation compression tests are shown in the order of the relative size of the two pieces.

Table IV. are tests of bricks from New Jersey clay in averages of series.

Table V. are tests of bricks from Iowa clay in averages of series.

The theory that the compressive strength of sand-lime bricks is generally reduced by saturation is, I think, fully established by the evidence so far obtainable. They are of almost absolutely uniform density throughout their whole length, and the uniform breaking of them at the point of application of power in the transverse test proves their uniformity in strength. This uniformity in breakage insures equality of area in the two pieces, and therefore eliminates the possibility of error due to difference in area.

The specifications made by the Building Department of Manhattan I consider entirely reasonable for a new structural material, and while I do not place much stress upon the compressive strength of bricks, the comparison between the dry and saturated compression of sand-lime bricks I deem as

important in showing the degree to which the chemical action between the silica and lime has taken place.

Of the test required I consider the transverse test of by far the greatest importance.

I have never seen bricks which were crushed under the normal load in the building, while I have seen many hundreds which have been broken transversely by a slight settling of the foundation, or uneven bedding of the bricks in the mortar.

By reference to Table VI. it will be seen that the ratio of modulus of rupture to compression is approximately as 1:7 whether singly or in the total average, and while the absorption varies in the different series from 1:20 to 1:35 as compared with modulus of rupture, it is reasonably uniform in each series.

These facts would indicate that any manufacturer having had a series of tests made with his own bricks of which he had obtained accurate dry weights can, with the dry weight and modulus of rupture, deduce reasonably accurate conclusions as to compression and absorption.

The absorption tests of bricks should be stated in percentage of volume instead of percentage of weight.

Of two bricks of the same dimensions, one of which weighs five pounds and the other four, the same percentage by weight would give for the heavier brick a larger percentage by volume, and as it is by reason of the increase of volume by freezing that the brick would be destroyed, it is evident that the heavier bricks would be the more subject to destruction, other things being equal.

This is illustrated in Table VII., tests of slag-sand-lime bricks made by the author. The brick weighing 73 ozs. is shown to have had an absorption of 15% by weight, equal to 13.60% by volume. Had the 44 oz. brick shown an absorption of 15% the volume would have been 8.21%.

It would require a proportion by weight of 24.85% in the 44 oz. brick to have equaled in volume the 15.00% in the 73 oz. brick.

Theoretically, capillary action should increase with increase of porosity, but it does not prove to be always the case.

Pieces measuring 1½ by 2 by 4 inches were cut from two different blocks made from sand and cement. The cement was from the same sack and the same measured quantity was used. One piece was made from Allegheny River sand, the other from slag sand. The two pieces were placed on end in one-half inch of water. When the water had reached the top of the river sand block it was only half-way up on the slag sand block, while the time required for the water to reach the top of the slag sand block was several times that of the river sand block, and the porosity of the slag sand block was 25% greater than the river sand block.

In the tests of S. V. Peffel, shown in Table VI., it will be observed that the compression strength of sand-lime bricks is increased by freezing. This is corroborated by other authorities, and would appear to be the rule when the absorption is low. No good theory has as yet been suggested to account for it.

In Table VII. it will be observed that slag-sand-lime bricks show an increase with age.

That the comparative fire-resisting qualities of bricks made from different materials can only be determined by subjecting them to the same conditions of test to which they would be subject in practice, was demonstrated by experiments recently made by the writer.

A common fire brick of a quality used only for flues and chimneys placed in the hot bottom of a heating furnace, with the gas flame passing over and around it at 2400 degrees F., did not show any perceptible effect at the end of 24 hours.

A silica brick, such as is used in the reverberatory arch of an open-hearth furnace, where it is subject to a continuous temperature of 3000°F plus, was destroyed when placed in a position similar to the fire brick, but subject to only 1000 degrees of temperature for the same length of time. The fire test should be made with the brick in such position that the direct heat reaches only the edge, as in a wall.

I have said that I consider the specifications made by the Building Department of Manhattan entirely reasonable for a "new structural material." Neither sand-lime bricks nor

cement blocks can be so considered. They have both been used for many years in countries where inspection is much more rigid than in the United States and have been subjected to the fire tests many times both in laboratory and conflagration. Any such material passing the other tests will surely resist the action of fire. It is no more reasonable than would be the subjecting to a fire test of the product of a new manufactory of kindling wood. The only guarantee of good concrete is the intelligence and reputation of the engineer and contractor.

TABLE I.

Tests of common bricks, made by Prof. Ira H. Woolson, E. M., of Columbia University, for the Building Department of Manhattan, and published in the Engineering News, April 13th, 1905.

HUDSON RIVER COMMON BRICK.

P., pale; M. medium; H. hard.

Series.	No.	Modulus of Rupture.	Compression Dry.	Compression Wet	Absorption in 48 h. %	Compression Reduction %	Compr'n Increase %
1.—	1 M.	779	5341	....	....	....	....
	2 P.	389	4035	1431	14.5	....	....
	3 M.	846	3415	2255	11.1	34.0	....
	4 M.	925	4393	3156	12.6	26.1	....
	5 P.	992	4545	....	....	....	....
	Average.	786	4346	....	12.7	....	....
2.—	1 M.	381	5260	....	....	....	....
	2 M.	520	4783	....	....	....	....
	3 M.	435	4800	4377	13.8	8.8	....
	4 M.	543	4557	4398	12.9	3.5	....
	5 H.	386	6420	4110	14.7	36.0	....
	Average.	435	5168	....	13.8	....	....
3.—	1 P.	489	1607	1905	20.0	....	19.0
	2 P.	367	2767	....	....	....	....
	3 M.	390	5129	4212	13.6	17.9	....
	4 P.	309	2436	....	....	....	....
	5 M.	306	3579	2460	21.0	26.2	....
	Average.	372	3108	....	18.2	....	....

TABLE 1.—CONTINUED.

Series.	No.	Modulus of Rupture.	Compression Dry.	Compression Wet	Absorption in 48 h. %	Compression Reduction %	Compr'n Increase %
4.—	1 M.	442	4748	3040	14.8	35.9	....
	2 P.	373	2971	....	....	....	....
..	3 M.	396	4790	....	....	....	....
	4 M.	444	5600	2833	15.7	49.5	....
	5 M	279	6336	4046	9.2	36.3	....
	Average.	367	4893	....	13.2	....	....
5.—	1 P.	401	2356	2456	18.5	....	4.2
	2 H.	230	4895	....	....	....	....
	3 P.	412	3611	3660	13.7	....	1.4
	4 H.	471	5310	....	8.2	....	....
	5 M.	491	4820	....	....	....	....
	Average.	401	4198	....	13.4	....	....
6.—	1 P.	136	2466	2478	20.6	....	....
	2 M.	464	4246	2984	16.8	29.7	....
	3 M.	311	3680	....	....	....	....
	4 M.	476	4759	2442	19.1	48.6	....
	Average.	348	3788	....	18.8	....	....
7.—	1 M.	749	2529	2863	14.4	....	13.2
	2 M.	286	3306	4511	12.2	....	36.4
	3 M.	649	2240	4200	11.9	....	87.7
	4 M.	291	5753	....	....	....	....
	Average.	494	3457	....	12.8	....	....
8.—	1 M.	532	2312	1812	10.0	21.6	....
	2 M.	550	3835	2555	17.8	33.4	....
	3 P.	248	1952	2030	14.1	....	4.0
	4 M.	368	2467	3203	14.1	....	30.0
	5 M.	382	2890	2822	18.1	2.3	....
	6 M.	643	2750	1777	16.0	35.4	....
	Average.	453	2701	....	15.8	....	....
9.—	1 M.	442	4882	....	14.9	....	....
	2 M.	160	2720	2942	19.3	....	8.2
	3 M.	382	2395	1718	17.2	28.2	....
	4 P.	297	2463	....	....	....	....
	5 M.	243	2336	....	....	....	....
	Average.	305	2959	....	17.1	....	....

TABLE 1.—CONTINUED.

Series.	No.	Modulus of Rupture.	Compression Dry.	Compression Wet.	Absorption in 48 h. %	Compression Reduction %	Compr'n Increase %
10.—	1 M.	633	5226	3390	13.8	35.1	....
	2 M.	777	5336	....	....	....	....
	3 M.	805	5410	3755	15.2	30.6	....
	4 H.	**212**	5908	5550	12.0	6.0	....
	5 M.	1010	5182	....	....	....	....
	Average.	687	5416	....	13.7	....	....
11.—	1 M.	474	2751	2723	15.9	1.1	....
	2 M.	633	5270	4143	14.1	21.4	....
	3 M.	570	8944	....	....	....	....
	4 M.	656	4008	....	....	....	....
	5 M.	441	2926	2712	15.6	7.3	....
	Average.	**553**	4786	....	**15.2**	....	....
12.—	1 M.	375	2800	....	....	....	....
	2 H.	503	**2396**	1732	8.8	27.7	....
	3 M.	**250**	**2080**	1141	13.4	**45.1**	....
	4 M.	464	2617	2260	13.9	**37.6**	....
	5 H.	435	2694	....	....	....	....
	Average.	**405**	**2717**	....	12.0	....	....
13.—	1 M.	645	3891	2584	18.8	**33.6**	....
	2 M.	798	3619	2954	17.8	18.4	....
	3 M.	863	4464	2619	16.9	**41.4**	....
	4 P.	607	2713	....	....	....	....
	5 M.	553	4065	....	....	....	....
	Average.	689	3750	....	**17.8**	....	....
14.—	1 M.	675	4482	3622	16.9	19.2	....
	2 M.	656	2744	....	....	....	....
	3 M.	626	3463	4454	15.6	....	27.3
	4 M.	882	3728	3593	11.4	3.9	....
	5 H.	368	3714	....	....	....	....
	Average.	642	4040	....	14.0	....	....

Bold faced type indicates points below specifications.

Number of each kind of test made.

Series	Brick	Modulus of Rupture	Compression Dry	Compression Wet	Absorption 48 h.	Difference %
14.—	69	69	69	43	45	42
No. of tests which fall below specifications:						
13.—	28	14	13	....	2	8
No. of series averages below specifications:						
10.—	....	7	3	....	6	

TABLE I.—CONTINUED.

PHILADELPHIA PRESSED BRICK.

Series	No.	Modulus of Rupture	Compression Dry	Compression Wet	Absorption % in 48 h.	Compression Reduction %	Comp'sion Increase %
15.—	1 M	1391	8283	7944	7.3	4.1	....
	2 M.	1550	9425	7680	5.8	18.5	....
	3 M.	541	5293	5650	12.2	....	6.7
	4	*137	4997	5414	12.2	....	8.5
	5	*476	3524	2973	12.4	15.3	....
	6	957	6637	....	....	....	....
	Average.	†983	6361	5932	10.0	....	....

*Fire crack. †No. 4 omitted.

TABLE II.

Bricks below standard of specification arranged in order of tensile strength, crushing strength, absorption and reduction.

Kind.	Modulus of Rupture.	C. Dry.	C. Wet.	Absn.	Redn. %	Inc. %
P.	136	2466	2478	20.6	....	.0
M.	160	2720	2942	19.3	....	8.2
H.	212	5908	5550	12.2	6.0	....
H.	230	4893	....	....	....	....
M.	243	2336	....	....	....	....
P.	248	1952	2030	18.1	....	4.0
M.	250	2080	1141	13.4	45.1	....
H.	279	6336	4046	9.2	36.3	....
M.	285	3506	4511	12.2	....	36.4
M.	291	5753	....	....	....	....
P.	297	2463	....	....	....	....
M.	306	3579	2640	21.0	26.2	....
P.	309	2436	....	....	....	....
M.	311	3680	....	....	....	....
Average.	254	3579	3167	14.4	28.4	16.3
P.	489	1607	1905	20.0	....	19.0
P.	248	1952	2030	18.1	....	4.0
M.	250	2080	1141	13.4	45.1	....
M.	649	2240	4200	11.9	....	87.7
M.	532	2312	1812	11.0	21.6	....
M.	243	2336	....	....	....	....
P.	401	2356	2456	18.5	....	4.2
M.	382	2395	1718	17.2	28.2	....

TABLE II.—CONTINUED.

Kind.	Modules of Rupture.	C. Dry.	C. Wet.	Absn.	Redn. %	Inc. %
P.	309	2436	....	....	....	....
P.	297	2463	....	....	....	....
P.	136	2466	2478	20.6	....	.0
M.	368	2467	3203	14.1	....	30.0
H.	503	2396	1732	8.8	27.7	....
Average.	367	2270	2267	15.4	30.6	29.0
P.	136	2466	2478	20.6	....	.0
M.	306	3579	2640	21.0	26.2	....
Average.	221	3022	2559	20.8	....	....
M.	550	3835	2555	17.8	33.4	7.4
M.	545	3891	2584	18.8	33.6	18.3
M.	846	3415	2253	11.1	34.0	8.1
M.	641	2750	1777	16.0	35.4	....
M.	464	3617	2260	13.9	37.6	32.6
M.	863	4464	2519	16.9	41.4	2.6
M.	476	4759	2442	19.0	48.6	24.2
M.	444	5600	2833	15.7	49.5	21.0
Average.	616	4041	2415	16.1	39.2	15.3

TABLE III.

Bricks showing increase and reduction of compression after saturation as compared with compression dry, arranged in the order of their variation in size.

Kind.	M. of R.	Comp. Dry.	Comp. Wet.	Absn. %	Redn. %	Inc. %	Size.
M.	626	3463	4454	15.6	....	27.3	22.7
P.	136	2466	2478	20.6	....	00.0	.0
P.	489	1607	1905	20.0	....	19.0	9.2
M.	649	2240	4200	11.9	....	87.7	9.5
M.	368	2467	3200	14.1	....	30.0	12.8
M	749	2529	2863	14.4	....	13.2	21.8
M.	160	2720	2942	19.3	....	8.2	32.4
P.	412	3611	3660	13.7	....	1.4	32.6
P.	401	2356	2456	18.5	....	4.2	35.6
P.	248	1952	2030	18.1	....	4.0	35.8
M.	286	3306	4511	12.2	....	36.4	56.6
Average.	411	2611	3154	16.2	....	21.0	....

TABLE III.—CONTINUED.

Kind.	M. of R.	Comp. Dry.	Comp. Wet.	Absn. %	Redn. %	Inc. %	Size.
M.	882	3728	3593	11.4	3.9	....	**25.6**
M.	645	3891	2584	18.8	**33.6**	....	**18.3**
M.	**306**	3579	2640	**21.0**	26.2	....	**.0**
M.	863	4464	2619	16.9	**41.4**	....	.2.6
H.	386	6420	4110	14.7	36.0	....	4.2
M.	675	4482	3622	16.9	19.2	....	6.5
H.	**279**	6336	4046	9.2	36.3	....	7.4
M.	550	3835	2555	17.8	**33.4**	....	7.4
M.	846	3415	2255	11.1	**34.0**	....	8.1
H.	503	**2396**	1732	8.8	27.7	....	9.8
M.	474	2751	2723	15.9	1.1	....	12.0
M.	805	5410	3755	15.2	30.6	....	14.0
M.	633	5270	4143	14.1	21.4	....	14.4
M.	532	**2312**	1812	11.0	21.6	....	17.7
M.	382	**2395**	1718	17.2	28.2	....	18.1
M.	444	5600	2833	15.7	**49.5**	....	21.0
M.	925	4393	3156	12.6	26.1	....	21.1
H.	**212**	5908	5550	12.2	6.0	....	23.0
M.	633	5226	3390	13.8	35.1	....	23.0
M.	464	4246	2984	16.8	29.7	....	23.3
M.	798	3619	2954	17.8	18.4	....	23.4
M.	442	4748	3040	14.8	35.9	....	23.7
M.	476	4759	2442	19.1	**48.6**	....	24.2
M.	453	4557	4398	12.9	3.5	....	24.4
M.	435	4800	4377	13.8	8.8	....	28.3
M.	441	2926	2712	15.6	7.3	....	30.3
M.	464	3617	2260	13.9	**37.6**	....	32.6
M.	390	5129	4212	13.6	17.9	....	33.3
M.	**250**	**2080**	1141	13.4	45.1	....	38.1
M.	382	2890	2822	18.1	2.3	....	....
M.	641	2750	1777	16.0	**35.4**	....	....
Average.	536	4127	3030	14.9	25.8	....	18.4

Size; percentage of piece compressed dry, which piece compressed wet was of greater or less area. Greater area in bold faced type.

TABLE IV.

Bricks of New Jersey Clays.

From the Geological Surveys of New Jersey.

				Modulus of Rupture			Comparison per Sq. In.		
No.	STIFF MUD	Color	Burn	Max.	Min.	Ave.	Max.	Min.	Ave.
1	Side cut, repressed.....	Buff	Hard	828	1471	1145	13260	15590	13873
2	End cut.....	D. Red	Normal	455	1349	874	1845	2760	2124
3	" "	L. Red	"	608	922	755	3410	4620	3820
4	" "	Red	"	271	784	513	1277	2740	2012
5	" "	Red	"	622	1350	1003	580	2280	1694
6	Side "	D. Red	"	558	739	659	3250	5850	4533
7	End "	Red	"	416	725	559	1680	2070	1823
16	Side " repressed	Buff	Hard	912	1232	1094	4740	6975	5858
17	End " "	White	"	922	1205	1060	6820	7925	7429
19	Side "	D. Red	"	1272	1725	1459	3550	9260	6288
	Soft Mud								
21		L. Red	Normal	124	155	141	555	748	661
26	Hand made.....	D. Red	"	328	492	440	2205	3760	3107
27	" " repressed...	D. Red	"	420	780	613	3838	4850	4307
30		D. Red	"	673	870	781	2120	3840	3051
31	repressed...	D. Red	Hard	1046	1323	1042	5535	6470	5909
	Nos. 26&27 from same yd.								
	" 30&31 " "								
	Dry Pressed								
32		Brown	Hard	1338	1455	1397	9125	16675	13525
33		Buff		1288	1448	1367	11360	14436	12998
34		Buff		852	1162	985	6140	7300	6760
35		Buff	Hard	752	883	831	4370	7050	5583

TABLE V.

Tests of Iowa Common Brick.

From Bulletin No. VI., Iowa State College, by Director A. Marston,

KIND OF BRICK	Transverse Strength lbs. per sq. in.	Crushing Strength lbs. per sq. in.	Per Cent. Absorption	No. Freezings to Destroy 1" Cube	Ratio $\frac{C}{T}$	Product $T \times A$	Ratio $\frac{T}{F}$	$R = T + \frac{C}{5} + \frac{9000}{A} + 65F$	$R = 2T + \frac{9000}{A} + 65F$
Council Bluffs	T	C	A	F					
Pavers	1620	16800	4.7	100	10.4	7600	16.2	13400	11700
Webster City Common	740	3060	9.5	90	4.1	7000	8.2	8100	8300
Dale Common	610	3900	15.4	81	6.4	9400	7.5	7200	7100
Grand Junction Lt. Col. Common . . .	990	5180	12.3	49	5.2	12200	20.3	6000	5900
Grand Junction Common	840	4720	13.5	45½	5.6	11300	18.5	5400	5300
Grand Junction Average	910	4950	12.9	47	5.4	11700	19.4	5700	5600
Kelly Soft	300	1930	20.5	51	6.4	6200	5.9	4400	4300
Mason City Common	890	4660	12.1	19	5.2	10800	47.0	3800	3800
Mason City Common	1170	4460	13.8	15	3.8	16100	78.0	3700	3900
Mason City Average	1030	4560	13.0	17	4.5	13400	60.6	3700	3800
Council Bluffs Soft	230	1790	22.6	34	7.8	5200	6.8	3200	3100
Ames Common	280	1510	22.7	31	5.4	6300	9.0	3000	3000
Ames Common	230	1470	21.8	27½	6.4	5000	8.4	2700	2700
Ames Common Average	230	1490	22.3	29	5.9	5600	8.6	2800	2800
Kelly Common	420	2240	21.4	17	5.3	9000	24.8	2400	2400
Dale Soft					5.1	6900	27.8	2000	2000
Average 6 Common	660	3370	15.7	47	5.3	9400	21.5		
Average 3 Soft	300	1850	20.8	33	6.4	6100	13.5		

Transverse tests averages of 25 bricks each. Other tests averages of 10 each.

It will be seen that some of these ratios are subject to wide fluctuations and the average values are not to be taken as yet well established by the results of this single series of tests. For a rating formula whose coefficients are approximately determined we may take, however.

$$R=T+\frac{C}{5}+\frac{9000}{A}+65F.$$

In which R is a ranking number.

T—Transverse modulus of rupture in pounds per sq. in.

C—Crushing strength in pounds per sq. in.

A—Per cent of absorption in 48 hours.

F—The number of freezings to demolish a one-inch smooth cube.

This subject is one which demands considerable further investigation.

Crushing tests are difficult and expensive. In case they have not been made the transverse strength may be given double weight, making the formula,

$$R'=2T+\frac{9000}{A}+65F.$$

In the above table the values of R′ are also given and it will be seen that they rank its brick in the same order as R.

TABLE VI.

Tests of Sand-Lime bricks made by Prof. Ira. H. Woolson, E. M., for the American Sand-Lime Brick Association.

		Compression lbs. per sq. in.				Modulus of Rupture			Absorption	
Series	No.	Dry	Saturated	Reds Per Cent.	After Freezing	Dry	Saturated	Red Per Cent.	Per Cent. Wt.	Per Cent. Lime
A.	16	2507	2100	16.0	....	347	....	....	11.5	....
	17	2088	1587	24.0	....	271	....	....	15.4	....
	18	2761	1680	39.2	....	288	....	....	12.0	6.0
	19	2645	1616	38.9	....	326	....	....	12.0	....
	20	2421	1674	30.9	....	360	....	....	15.2	....
Average.		2484	1811	29.9	1596	320	248	21.3	13.5	....
B.	16	2627	2031	22.7	....	492	....	....	17.5	....
	17	2966	2100	29.4	....	456	....	....	17.7	....
	18	2404	2267	5.7	....	479	....	....	17.6	10.0
	19	3033	2492	19.6	....	535	....	....	13.1	....
	20	2828	1971	30.2	....	547	....	....	18.1	....
Average		2772	2174	21.5	1819	505	349	51.4	16.8	....

TABLE VI.—CONTINUED.

Series	No.	Compression lbs. per sq. in. Dry	Saturated	Reds per Cent.	After Freezing	Modulus of Rupture Dry	Saturated	Red Per Cent.	Absorption Per Cent. Wt.	Per Cent. Lime
C.	16	2805	1957	30.5	....	425	....	....	14.2	....
	17	2656	1996	24.9	....	396	....	....	13.9	....
	18	2745	2175	20.8	....	415	....	....	14.5	5.0
	19	3450	2209	36.5	....	436	....	....	14.4	....
	20	2302	2157	25.8	....	390	....	....	9.4	....
Average.		2792	2097	27.7	2265	406	345	11.9	13.3	....
D.	16	2405	1619	22.7	....	308	....	....	15.8	....
	17	2539	1980	22.0	....	418	....	....	18.4	....
	18	2720	2192	19.4	....	326	....	....	13,3	4.5
	19	2634	1768	33.1	....	323	....	....	15.4	....
	20	2984	2056	31.1	....	354	....	....	14.7	....
Freezing test; 20 times at 0°; thawed in water at 120°.										
Average.		2626	1923	27.7	1174	334	241	21.2	15.5	....
G.	16	4620	2916	36.9	....	632	....	....	13.2	....
	17	3539	2012	43.2	....	516	....	....	13.1	....
	18	2684	1845	31.3	....	440	....	....	12.2	5.0
	19	3317	2096	36.0	....	536	....	....	15.2	....
	20	2906	2044	29.7	....	544	....	....	13.5	....
Average.		3413	2183	35.6	1739	494	485	0.9	14.2	....
Total Ave.		2817	2039	....	....	412	....	....	....	....

Tests by S. V. Peppel, B. Sc., for Ohio Geological Survey.

No.	Compression lbs. per sq. in. After Hardening	After Aging		After Freezing				Absorption % Wt.	
85	2766	2449	....	2917	....	....	....	8.3	....
83	3697	....	....	3812	....	....	....	8.6	....
90	5607	5843	....	7524	....	....	....	....	....
93	3835	3955	....	4502	....	....	....	8.6	....
88	1705	1325	....	1477	....	....	....	9.0	....

TABLE VII.

Tests of Various Bricks.

Made by Jos. A. Shinn, at Pittsburg.

Kind.	Wt. Ozs.	Compression sq. in. 7 days.	28 days	Absorption. % Wt	% Vol.	Lime % Ca. O.
Slag Sand-Lime	44	601	762	10.00	5.47	7.0
" "	53	1331	1367	10.00	6.58	7.0
" "	71	1210	1536	15.86	13.97	4.2
" "	73	1750	1894	15.00	13.60	6.4
" "	76	1701	1970	14.89	14.00	7.0
" "	79	2046	2662	12.10	11.88	5.6
" "	81	2200	3035	12.00	12.24	7.0
" Ground	81	5684	5661	10.00	10.08	7.0
" "	86	7646	9000	10.00	10.94	....
Red Clay, Medium..	88	1590	....	10.00	10.94	....
" Hard ...	94	2340	....	10.00	11.66	....
" Repressed	110	6443	....	10.00	13.67	....
" Common hard	99	3149	....	10.00	12.24	....
" " "	105	3279	....	10.00	1296	....
Fire Common	112	1127	....	10.00	13.70	....
" "	120	1231	....	10.00	14.90	....
Cement 1; sand 3.						
Portland		2030	3030	.....	....	Tetmajer
Slag Puzzuolani ...		1764	3030	.....	....	"
" Portland		2706	4471	.....	....	Passow
Eisen Portland		2422	4218	.....	....	"

Eisen Portland; 54% Slag Portland and 46% ground slag.

When 10% is given as absorption by weight it is for the purpose of illustrating difference between weight and volume and not actual absorption.

PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXII DECEMBER, 1906 No. 9

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

*MACHINE SHOP COSTS.

†WM. CUNNINGHAM.
Non-Member.

The scope of the term "Machine Shop Costs" may be better understood when it is explained that it includes practically the same general principles governing all that is expressed in the broader term—Factory Accounting. For this reason it is next to impossible to give due consideration to the subject as a whole, within the limits of a paper to be prepared for any one evening. In view of this fact it was suggested to your Secretary, in accepting this invitation extended by the Society, that he indicate, if possible, the particular divisions or features of the subject, which, in his opinion, the Society might prefer to have presented. In due course a letter was received from the member who suggested the topic, and from it the following is quoted:

"I believe a description of the methods followed by the interests with which you are connected (the Westinghouse Electric and Manufacturing Company) in keeping costs would

*Meeting Mechanical Section, October 2, 1906.
†Westinghouse. Elec. & Mfg. Co., East Pittsburgh, Pa.

be of great interest to the members of this Society. There is doubtless a wide range of accuracy in different works and it is a question sometimes, of how much refinement of system is desirable."

In so far as possible the member's suggestion will be considered in what follows, but it is doubtful if the original task involved is reduced to any considerable extent.

To intelligently determine what refinement of cost accounting is necessary and advisable in any manufacturing business, it is first necessary to consider the character of the product being manufactured, and second, it is important to know the conditions under which it is marketed. The character of the product is mentioned as being first in importance, because it decides very largely the cost accounting practices required to support the purely general accounting necessities.

If the product is not a varied one and the character and design is of a permanent character, so much so that such changes as may be made from time to time do not affect the cost of the product to any appreciable extent, then the question of the cost accounting becomes a somewhat simple proposition, not only with respect to the needs of the manufacturing and selling departments but probably more particularly so, with regard to the requirements of the accounting department for general accounting purposes. Such costs of product as might be necessary under these conditions could, no doubt, be estimated with sufficient accuracy for all the purposes for which they would probably be required. If it were advisable to determine in certain instances what in these days are termed "Actual Costs," it would probably be necessary to prepare such costs only intermittently.

For such a product it would only be necessary to determine the cost of the indirect labor performed and of the expense of material used, both of which comprise what is variously termed as, "overhead charges," "factory burden" and "factory expense." These expense charges must be arrived at before any statement of earnings, expenses and profits, either monthly or less often, is prepared. It would be unwise and

contrary to what is generally understood to be sound accounting practice, to use an estimate of these factory expenses without a means of ascertaining the actual expenses periodically so that whatever differences there might be could be properly adjusted.

On the other hand, a product varying greatly in both character and design will also, very probably, vary considerably in cost, but because of no considerable competition, the product may be marketed without difficulty and with a margin of profit so satisfactory that, so far as the selling and manufacturing departments are concerned, such costs as they might require could probably be prepared on an estimated basis. Under these manufacturing conditions, however, the cost values thus obtained, while probably satisfactory for the use of the selling and manufacturing departments, could not be considered reliabe for use by the accounting department in preparing statements of earnings, expenses and profits.

To properly safeguard, then, the general or controlling accounts of a manufacturing business, in which the character and design of the product vary so greatly as they do for example in the product manufactured by the Westinghouse Electric & Manufacturing Company, it is fundamentally necessary that there be a means by which to ascertain, as correctly as it is possible to do so through reports prepared by the various works departments, the cost of the materials actually used, the labor actually performed and the proportion of "factory expenses" to be applied, upon each unit of apparatus completed and delivered to the storekeeper, either for shipment or for withdrawal by the works to be assembled with other apparatus. For the purpose of general accounting it is unnecessary that there should be any further refinement of cost accounting than that necessary to ascertain the total cost of each unit of apparatus manufactured. Costs detailed to individual parts and operations are of use to the engineering and manufacturing departments only, and therefore such additional refinement of cost system as may be necessary to prepare costs thus detailed, must be determined by the practical use that can be made of such information.

To arrive at only the total cost of each unit of apparatus completed in the works of this company, is, of itself a huge undertaking, as you may appreciate, considering the variety of type and design of the product. The organization of the manufacturing department of any company may of necessity be such that difficulties out of the ordinary are met with in the processes of cost finding, and this is the situation prevailing to a considerable extent with this company.

The manufacturing organization of the works of this company includes approximately one hundred producing departments. Each of these departments is equipped to perform a certain class of operations upon specific parts, regardless in most cases, of the type, design or size of either the finished part or the completed unit with which the part may finally be assembled. Of the one hundred departments, eight are assembling departments and to these eight, all of the other ninety-two contribute either directly or through the various finished stock storerooms, such portions of the finished product as each department is especially equipped to manufacture. For instance, in the manufacture of a certain unit of apparatus of 200 kilowatt capacity, twenty-one departments are involved, each performing labor and using material on a certain part or parts necessary to the completion of the apparatus, and the labor performed and the material used by each department must be reported under the number assigned the order for the manufacture of the unit.

While such an organization concentrates manufacturing equipment of a kind, both operatives and machinery, thus specializing the manufacture of the product, and thereby contributing to both low manufacturing cost and high quality of work, it makes the problem of cost finding, as already stated, a difficult and complicated one, as compared with a factory so organized and equipped that each class of its entire product is manufactured complete in one department, or at the most, in only a few.

While under the first mentioned form of organization, the manufacturing operations are specialized, the manufacture as a whole is so decentralized that the number of order accounts

and records to be established and maintained is increased, as compared with the latter form of organization, by the difference in the number of divisions or departments identified with the manufacture of each unit or lot of units of apparatus for which a manufacturing order is entered. The result is that not only is the cost accounting made more difficult but also the problem of establishing and maintaining such records of manufacture as are necessary for the purposes of production exclusively, is also attended with correspondingly greater difficulties and greater expense.

The extent to which cost accounting is affected by the form of manufacturing organization employed may be further added to by the plan adopted for paying for labor. Of the many plans for compensating workmen for effort, probably those described as the "day work plan," the "piece work plan" and the "premium plan," employed as follows, are the ones in most common use in manufacturing pursuits.

DAY WORK PLAN.

Under this plan each workman receives a fixed rate per hour for each hour worked, regardless of the quantity of work performed.

PIECE WORK PLAN.

Under this plan each workman receives a fixed price per piece for certain work, regardless of the number of pieces upon which the work is performed or the time consumed.

PREMIUM PLAN.

Under this plan a time limit is fixed for certain work to be performed. The workman receives a fixed rate per hour for each hour he is engaged on the work and the same rate for one-half of the time in which he completes the work in less than the time limit fixed for the work. The premium feature in this plan is the extra compensation for the "time saved;" in all other respects it is the same as the "day work plan."

Without regard to the relative merits of these three plans for paying for labor, viewed from the standpoint of the manufacturing department i. e., to secure the maximum output with the minimum of cost and to duly compensate the workmen, the use of the day work plan simplifies the operations of cost accounting and the preparation of the pay rolls very considerably, as compared with either the piece work plan or the premium plan. To properly safeguard the preparation of the pay roll under the day work plan involves no difficulties out of the ordinary, since it is only necessary to certify to the correctness of the number of hours each employee reports having worked and this may be readily and satisfactorily accomplished by either of two reliable means—time-clocks or check-boards—the former preferably. The only factors to be considered in ascertaining the wages due workmen employed under this plan are—the time worked and the fixed hourly rate.

Where the product manufactured varies to any considerable extent it is necessary, as has already been stated, for the purpose of safeguarding the general or controlling accounts, to determine the acual cost of each unit of apparatus manufactured. To secure this result under any plan of paying for labor it is necessary that the workmen's reports of labor performed be so prepared that it will be possible to ascertain from them the cost of the labor performed upon each production order as completed.

Under the day work plan of paying for labor, it is unnecessary that the work performed be segregated on the labor reports further than as to order numbers, unless costs detailed to parts and operations are required for other than general accounting purposes.

Under the piece work plan the workmen's reports of work performed must specify, in addition to the order number, the specific work performed under each piece work price and also the number of pieces completed. To properly safeguard the wage disbursement under this plan, adequate provision must be made to secure reliable certification that the work reported completed by the workman has actually been performed, both as to number of pieces and the specific work performed on

them. Any inaccuracies in reporting this information will be included in the pay roll and either the workmen or the company may suffer loss thereby. Under the day work plan it may be necessary for the purpose of determining the stage of completion of work of any apparatus and for arriving at detailed cost, that the workmen's reports of labor should specify the operations performed and the number of pieces completed under each, but any inaccuracies in this respect would not be included in the pay roll as must be the case under the piece work plan.

This company believes that under its form of manufacturing organization the premium plan of paying for labor possesses greater advantages for securing the maximum of output with the minimum of cost, and at the same time providing due compensation to the workmen for effort expended, than either the day work or the piece work plans. To this end the premium plan has been adopted by this company.

Under the premium plan three factors are involved in determining the wage earned by the workmen, namely: the time limit, the number of pieces upon which the work included under any time limit is performed and also the time consumed. Under the piece work plan this latter factor—"time consumed"—is not a consideration in computing the wage earned, and thus under the premium plan there is an additional opportunity for error in certifying to the correctness of workmens' reports and in preparing the pay roll as compared with the piece work plan. It will be seen therefore that of these three plans of paying for labor, it is more difficult to secure proper certification of labor reports under the premium plan than under either the day work or the piece work plan.

It is the aim of this company to, as far as possible, compensate each workman for his individual endeavor, believing that his best effort will thus be secured. In other words, time limits are fixed as far as possible for the individual operations to be performed upon each piece of material, and this renders it possible to so distribute the work among the operatives that each can perform the work assigned him without being assisted by other workmen.

Under this arangement the workman's individual earning is not affected as it would be if working with others on a "company job," should the difference in the ability of the various workmen engaged on the work not be equalized by the difference in the fixed hourly rates.

The complications to be met in providing measures to secure accuracy in workmen's reports of labor performed under the premium plan, with the work segregated as explained, may be better understood in its application to a business of the magnitude of this company's when it is stated that there are upwards of from 500 to 1000 manufacturing orders in each producing department of the works at all times. Some of these orders are only intermittently active from the time they are entered until they are completed, but the majority are being worked upon continuously. From 10 to 30 individual labor operations are necessary to complete the work each department is required to perform on any one unit of apparatus, which means then, that there are from 5,000 to 30,000 labor operation accounts to which the labor performed in each department must be identified for the purpose of determining and safeguarding the wage disbursement.

From the foregoing it will be seen that the larger proportion of the detail in which it is necessary to secure reports of labor performance under the plan of paying for labor adopted by this company, is required to determine the wage to be disbursed periodically, regardless of the further use that may or may not be made of these details in the processes of cost accounting. Where the piece work plan is employed this condition obtains also.

We think is it now made clear that the plan of paying for labor may demand a more extensive refinement in the matter of reporting labor performances than that necessary for the purpose of preparing labor costs in sufficient detail to make them comprehensive for all purposes for which they may be used.

The routine followed by this company in valuing workmen's labor reports, the use of these reports in preparing the pay rolls and the distribution of the pay rolls to order and

operation accounts will not be described, as it probably differs little from that commonly employed by manufacturing interests in general.

With this Company, it is the responsibility of the storekeeper to enter orders for the manufacture of apparatus, and of the engineering department to issue the information necessary to guide the factory in the work to be performed. This information consists of bills of material and information sheets. Under the title "bill of material," there appears in the upper right hand corner of each drawing, a list of the kinds and quantities of materials required to make the part or parts indicated by the drawing. Copies of the bills of material are printed from the drawings and are issued to the various works departments and to the storekeeping and accounting departments. For each manufacturing order entered, the engineering department issues to the various departments, in addition to the bills of material, so called information sheets, which specify by drawing number and bill of material item number the kinds and quantities of the various materials to be used in the manufacture of the apparatus.

In addition to the use made of these information sheets and bills of material by the various works departments, they become the storekeeper's guide in maintaining stocks of standard materials and for ordering such special materials as may be required. They also serve an important function in the accounting department, in that they are used by that department as the basis for determining the cost of the materials used in the manufacture of any apparatus.

With respect to the element of cost referred to previously as factory expense, it is unfortunate that the conditions attending manufacturing operations in general, are such that the processes necessary to a thoroughly satisfactory determination of this very important factor of cost are usually impracticable of operation. The difficulties to be met in this connection vary according to the difference in the conditions of manufacture and because of the extent of these differences, it would be impossible to include in this paper any very comprehensive discussion of this division of the subject. With this company

the condtions are such that it has not thus far been found practicable to apply factory expenses other than by a general percentage on direct labor, this percentage being the relation of total factory expense to total direct or productive labor.

DISCUSSION.

L. C. Moore, Member—Has the premium plan given good results in your works?

Wm. Cunningham—I am not in a position to reply to this question definitely, as my connection is with the accounting department. The results of the operation of this plan of paying for labor are better understood by the manufacturing department because of its closer association with the conditions under which all factory labor is performed, generally, I believe I am warranted in saying that the results are entirely satisfactory. As already explained, it is more difficult to secure a reliable wage distribution under the premium plan than under either the day work or piece work plan. My personal opinion is, that with equal care in fixing a time limit and a piece work price, the incentive to the workman is about equal. The fixing of the time limit does not, however, determine the cost of the work, as in the case of making a piece work price. Under the premium plan, the cost varies according to the difference in the time consumed in performing the work. If the piece work price for certain work is based upon, say, ten hours for a workman, rated at 25 cents per hour, or $2.50 for the job, that is the cost of the work whether the workman completes the work in 5 hours or 15. If the time limit for the same job is, say, 10 hours, based also upon a workman rated at 25c per hour for performing the work, and the work is completed in 5 hours, the cost will be $1.87½ as compared with $2.50 under the piece work plan. For each hour in which the work can be performed in less than the limit time, the cost of the work is reduced and the workman's hourly earned rate is increased. If the workman consumes more than the limit time, the cost is increased as compared with a piece work price

based upon the same number of hours allowed under a time limit for the same job. The efficiency of the premium plan is difficult to satisfactorily determine in its application to the product manufactured by the Westinghouse Electric & Manufacuring Co., and this would be true of any other plan of paying for labor that might be employed. The reason for this is that a very large percentage of the product is of special manufacture, and even the so called "standard designs" undergo changes as frequently as twice and three times a year.

G. H. Danforth, Member—Do you add a flat rate to all productive labor for overhead charges of all kinds? If that is the case, with diversified product, my experience would indicate that the cheap work would be overloaded and the expensive work underloaded.

Wm. Cunningham—To do differently would involve us in complications that we have not thus far found a practicable means for taking care of. If the productive labor for any one month is, say, $100,000.00 and the factory expense $100,000.00, we would add 100% to each dollar of direct labor in figuring costs. We know that in departments where most of the labor is performed by hand, in departments where the less expensive machinery is used, that the costs we are getting are too high; we know also that the apparatus made in the departments using the heavier machinery costs something more than our costs show. Our sales department is familiar with this condition, and fixes the selling prices to equalize these differences as far as possible.

A. Stucki, Member—To come back to the question of wages; I understood Mr. Cunningham to say that they set a 1½ day rate limit in spite of the 50% premium system. I think if the premiums are based on the proper percentage, this system should not be limited at all, as the workman, by obtaining the premium, not only cheapens the rate of labor, but also increases the capacity of the machine and the shop. At the same time the "doctoring" of the time card will be done away with. I know of cases where such an unlimited premium

system has worked very well and done away with the well known defects of a limited piece work system.

WM. CUNNINGHAM—For each period of time that the workman can perform the work in less than the limit time, he increases his earned rate per hour and the cost of the work is reduced. Under a piece work plan the workman increases his earned rate but without a reduction in the cost of the work.

Mr. Stucki states he does not see what incentive there would be for the workman to "juggle" time. This "juggling" results from the fact that it is the belief among workmen, in shops where piece work or premium work of any kind is paid, that if a man makes more than one and a half times his fixed hourly rate, the result will be used by the company to reduce the time limit or piece work price on similar work to be performed later on other orders or jobs. That is the feeling and it is difficult to dissipate it, regardless of the fact that we do not change a time limit after it is fixed. If a man has made more than ordinary effort on a job and has made big earnings thereby, we do not use that information to his detriment. Of course, when extraordinary earnings are shown to have been made, these are taken up by the rate department, the conditions inquired into very carefully, and if it is found that the workman does not have to exert a great amount of effort to make the excessive earning, the rate department will arrange some other way to do the work. Divide it up into several operations which may have been included under one operation previously.

JACQUES NEGRU, Member—In fixing the wages of the workmen, don't you go back to the system of the man hired by the day, and only after a longer or shorter time, finding out the average price of a piece of work, for which the improvement is made, fix the price of piece work or the premium?

WM. CUNNINGHAM—When the work involved is something that we have never done before, we do not pay either premium or piece work the first time, we do it day work and feel our way. In each department there is a representative of

the rate department, and these men are studying the operating conditions continuously. They fix the time limits and afterwards the limits are approved by the foreman of the department, and the general foreman of the section of which the department is a part.

A. A. LANE, Member—I should like to hear from Mr. Cunningham just how costs are arrived at. Is the flat cost of material and labor used, or is the investment in various tools considered? Is no allowance made for the additional cost of an expensive tool?

WM. CUNNINGHAM—Our cost system does not provide that any specific charge be made for any tool used, except that included in the general percentage for factory expense. As stated previously, we try to take care of this difference in our selling department. The margin of profit is greater on the larger machines than on the smaller ones, because we know there is an element of cost in the former that we do not meet in the manufacture of the latter machines.

A. A. LANE—Take a shop, for instance, in which the operating expenses are known. Suppose a valuation is placed on every tool and on every square foot of floor space. On the basis of the floor space the tool takes, and the valuation of the tool with interest and depreciation, fix a rate for that tool, to which would be added the day wage of the man who operates it. Working that out carefully and taking the total of all the production capacity plus the burden in proportion to output, fix an absolute rate for every tool in the shop which would be practically correct. The point you mention regarding tools standing idle might be a difficulty, but in dull times you cannot charge on your work for the tools standing idle. Instead of doing that you would have to let them stand idle and reduce your costs as far as possible to get any work at all. That is an expense which the total earning or surplus must take care of. I believe that the cost of product could be figured out on the basis outlined, and give more accurate results than are obtained in most shops to-day. I know many shops do have a different rate for every class of tool.

WM. CUNNINGHAM—Take the case cited. The capital invested in the tool, the repairs to the tool, the proposition of floor space, etc., all this must be set up in a special account. To obtain a rate per hour, to charge for each hour the machine is employed, would require an estimate to be made of the number of hours the tool would probably be in operation during the year. Now, as I said before, how would it be possible to figure with any considerable number of machines the amount of time in a year that each would be idle? If an account is opened with each tool or a combination of tools, we have to credit these accounts from receipts of the time the tools are completed. Suppose at the end of a year, or any period of the time fixed upon, we find that the charges are running ahead of the credits—or the other way around, the credits ahead of the charges, what steps are to be taken then? These differences would result without doubt because the conditions of manufacture vary so greatly, and it is a question whether these differences would be so serious as to render the plan unsatisfactory. I think such a plan could be operated where the number of tools was small and the work did not vary too greatly.

A. A. LANE—In one way you have to do that same thing now. Take a large boring mill; you charge the time of it on a heavy casting at 40 cents an hour, when you know your depreciation, interest, power, etc., for that time may be $4.00, ten times what you have called it, and that is made up in your sales department. The question is whether that sales department comes anywhere near the proper charge on that particular machine.

WM. CUNNINGHAM—I think this should be an estimating proposition entirely, but at that, it would be little better than a guess.

A. STUCKI—Mr. Cunningham spoke about charging a certain proportion of general machines, which were purchased for a certain order, to that order, the balance being transferred

to the developing account. I would like to know exactly what disposition this is?

WM. CUNNINGHAM—When we purchase a tool that is an addition to the tool equipment, not a replacement, it is charged to capital account. But if we buy it to replace a tool that is worn out, then it is charged to an expense account. When we make tools to be used in the manufacture of special apparatus, and we do not know whether we will ever use the tools again, the cost is charged to the order as a part of the apparatus. We have the tools of course after the order is completed, and if we can use them again the cost of the next order on which they are used is reduced that much.

A. STUCKI—What is the approximate factory expense in different size establishments. About 60 to 100%?

WM. CUNNINGHAM—I have always understood that from 75 to 100% of the productive or direct labor should cover factory expense in the average manufacturing business. Of course I would not be at liberty to tell you what it is in our business, but I believe that is the range that is understood to apply to manufacturing in general.

A. A. LANE—I should like to ask Mr. Cunningham about his operating card.

WM. CUNNINGHAM—The operating card with us is a very important record. We could not get along without it under our form of organization, because of our endeavor to specialize the work so that each workman can, as far as possible, be paid for his individual effort. In the Baldwin Locomotive Works for instance all work is performed by contract. The contract is issued to a workman called the contractor and he pays all the men. We believe that each workman should be compensated as far as possible for his individual labor, therefore, we have very little "contract" or "company job" work. As I said there are in-

volved in the manufacture of any one unit from 20 to 25 operations. These operations are recorded in the operation cards in the departments in which the operations are performed. When information sheets are received from the engineering department for any order, the department clerk refers to the operation cards on file corresponding to the drawing number on the information sheets, and in that way is enabled to write up the labor sheet. In filling out these labor sheets, we specify every operation to be performed by the department on the order, and also under each operation the time limit for the operation. As the workmen's time reports are received at the foreman's desk they are posted to these labor sheets, and thus we have a means of certifying to the accuracy of these reports, particularly with regard to the number of pieces completed. I do not believe there is any way to absolutely check the time. We have tried time clocks and all that sort of thing, but unless you stand beside the man and watch him from the time he begins until he completes the work you don't know, nor is there any way to know the time actually worked.

*THE PITOMETER.

As Used in Waste Water Investigation.

†J. D. UNDERWOOD.
Member.

This paper will deal with the use of the Pitometer for locating leakage or theft of water from the mains and service pipes of a water works system, a general description of the instrument itself, and an account of a waste water investigation just made, covering one of the water systems supplying the City of Pittsburgh.

In general, the Pitometer is an instrument by which the velocity of water flowing in a pipe can be measured. It is an adaption of the Pitot tube, which has long been in use as a rather uncertain means of determining the velocity of streams of water in open conduits, and in connection with the photo-recording apparatus, will make records for extended periods of time showing every fluctuation of velocity of the water in the pipe on which it is set. From my own experience with the instrument I should say that its results are within about two per cent of absolute measurement. These records are capable of valuable deduction; for instance, if in a district of such character that little or no water should be used during the dead hours of the night, the record should show a considerable flow during these hours, it leads to the conclusion that there is leakage of water either through leaky mains, broken or unknown service pipes, or defective plumbing, gates or hydrants, which make a constant drain through the main. This conclusion is the basis of water waste investigation by this means.

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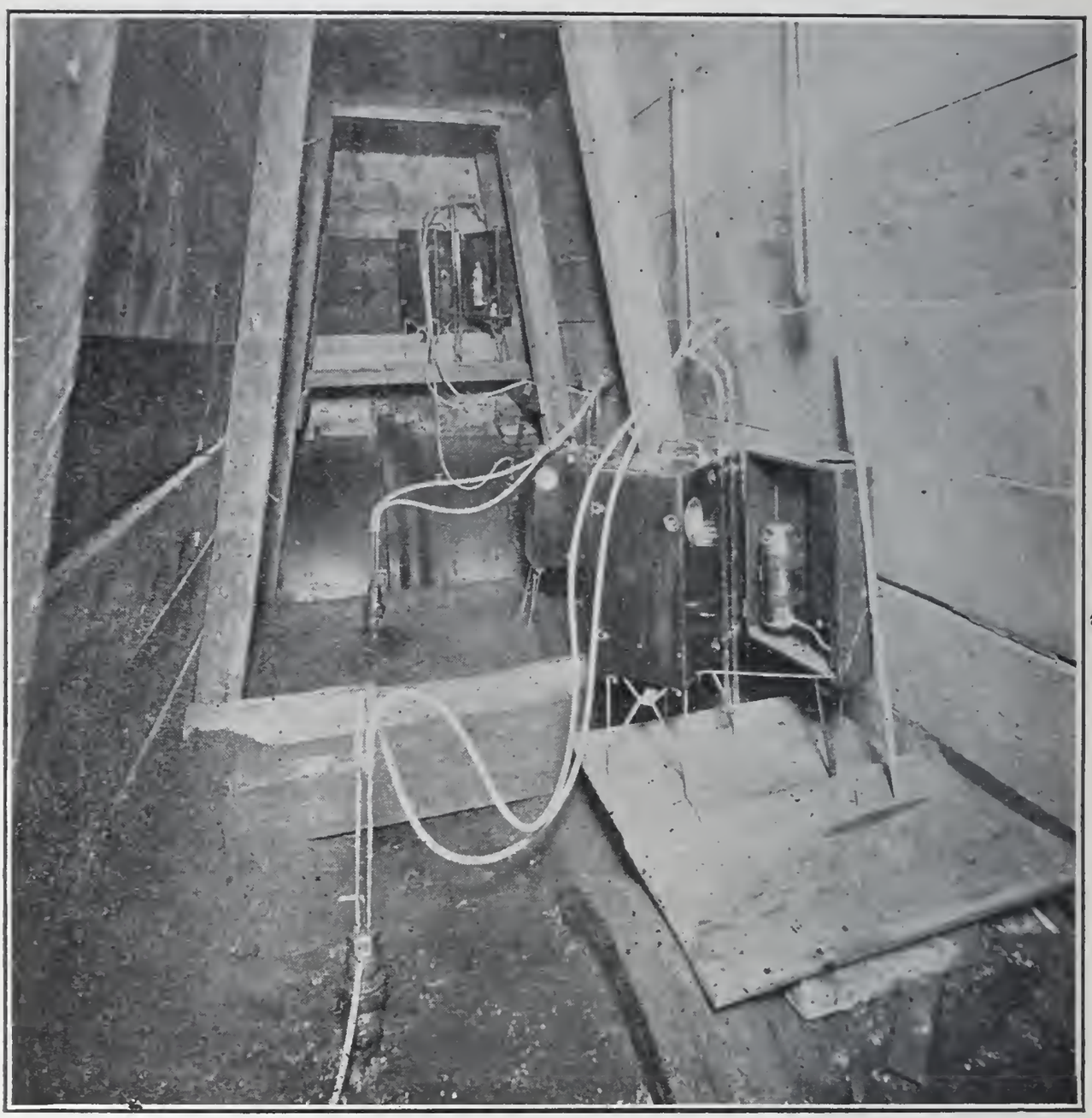
* Meeting Mechanical Section, October 6, 1906.
† City Hall, Pittsburgh, Pa.

The instrument itself consists of the rod meter and the photo recorder. The rod meter is a sheath of oval cross section, which encloses two $\frac{3}{16}$-inch brass tubes, which are free to turn in the sheath. These tubes pass through small stuffing



PITOMETER IN USE.

boxes at their upper ends, and are fitted with $\frac{1}{8}$-inch curved orifice pieces at the lower ends. By means of clips on the upper ends, these orifice pieces may be revolved through an angle of 180° or folded together. A gland and stuffing box which fits over the oval sheath allows connection to be made

to the regular Mueller or A. P. Smith ferrule or corporation cock, by means of which the main is tapped. In using the rod meter, after the ferrule has been inserted in the main, the gland on the oval sheath is screwed to the ferrule, the orifice pieces having been folded together and drawn up into the body of the gland. Rubber tubes are now connected with the upper ends of the brass tubes, and these in turn connect with a glass "U" tube, which is about half full of a mixture of carbon tetrachloride and gasoline, of known specific gravity, brought to a non-actinic color by the addition of iodine or other coloring matter. The key of the ferrule may now be turned allowing water to rise in the rubber tubes. By means of the drain tubes and pinch cocks provided, the air may be expelled from the tubes and replaced by a solid column of water. When all the air has been expelled the colored liquid in the two arms of the "U" tube will be level. The rod meter may now be pushed through the gland into the main, and the orifice pieces revolved through 180° so as to oppose each other. Thus, one orifice will be acted on by the extra pressure caused by the motion of the water in the main, in addition to the pressure due to the static head, which will be equal at both orifices. This difference in pressure will be transmitted through the rubber tubes to the surface of the liquid in the U tube, and will at once destroy its equilibrium, causing the liquid in the arm connecting with the up stream orifice to drop, and that in the other arm to correspondingly rise. The amount of this variation in a level is governed by the velocity of the water in the main, and by noting the distance between these levels, the velocity may be accurately determined, in the following manner.

In the formula $V=c\sqrt{2gh}$, "h" is the head in feet which is measured by the difference of level of the liquid in the U tube. When the liquid used has a specific gravity of 1.25, "h" is one quarter of the U tube deflection in feet, and when the specific gravity is 1.50, "h" is one half of the U tube deflection in feet.

In general the formula can be written thus;

$V=c\sqrt{2gh(x-1)}$ when V=velocity in feet per second, "c"= 0.80 (calibration coefficient of orifices); "g"=32.16, "h"=head in feet measured by the difference of level of the liquid in the U tube, "x"=specific gravity of the liquid used.

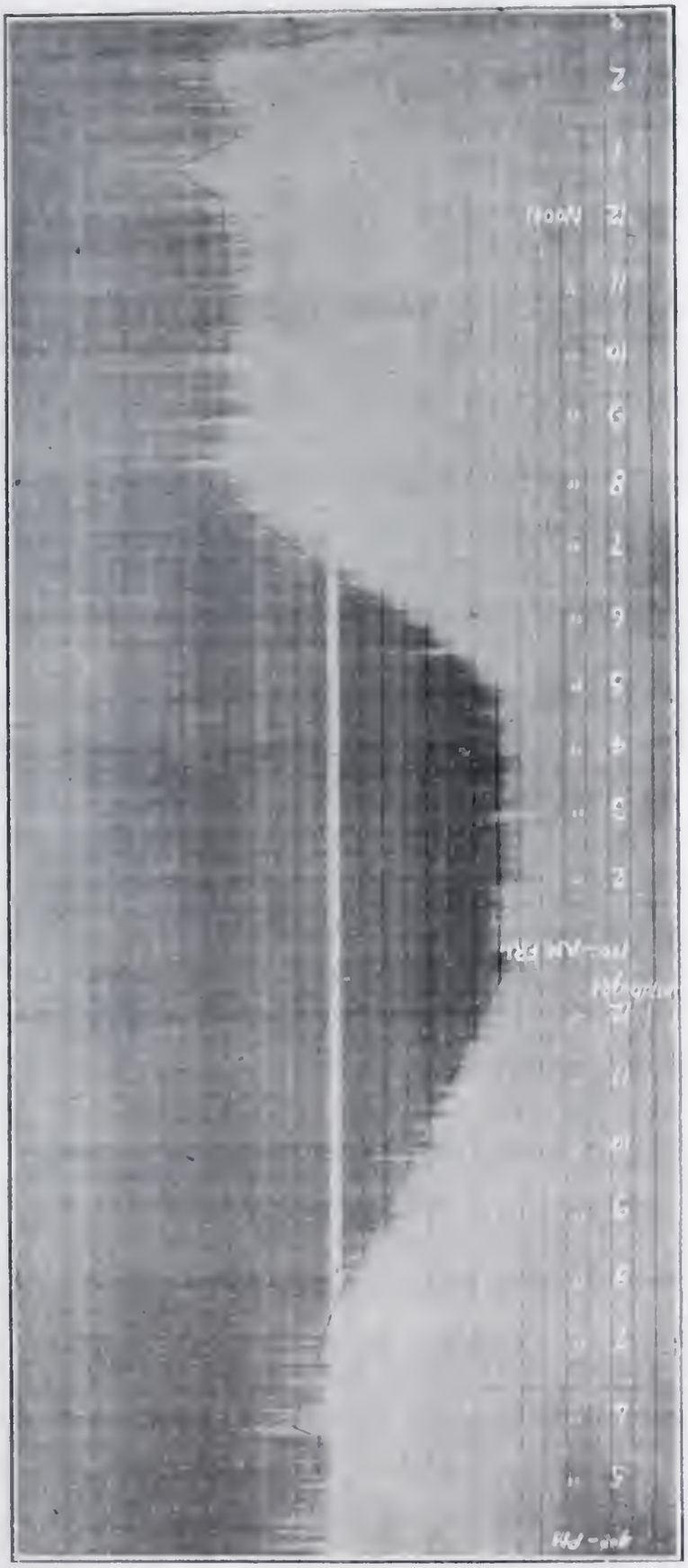
The calibration constant "c" of the orifices has been carefully and accurately determined, by repeated experiment, to be 0.80, and this value is used in all work with pitometer orifices of similar design to those used by the writer.

The above operation of taking the U tube deflections for determining velocity, is generally done with the orifices set at the point of greatest velocity in the cross section of the main, which is usually near its center. A further operation is necessary before calculating the flow from the velocity so obtained, as the water does not have the same velocity at all points in the cross section of the main. This operation is called taking the pipe traverse, and consists of obtaining a mean velocity by taking frequent readings of the tube deflections across the pipe, and dividing this by the maximum velocity, or that at the point where the orifices are to be located for the record. The resulting coefficient of velocity will be in the neighborhood of 0.80, and will be the same for the same location, no matter what the velocity of water in the pipe. When extreme accuracy is desired, the pipe traverse is taken through two ferrules set at 90° to each other, and the average of the two results taken as the coefficient.

The photo recorder, which is used when a record covering any considerable period is desired, consists of a case enclosing a drum actuated by clock work, a lamp, and a support for the "U" tube, so arranged that the light of the lamp is projected through the tube upon the surface of a sensitized paper which is wrapped about the drum, thus photographing upon the paper a record of the fluctuations of the surface of the colored liquid.

At the end of the record period, this paper is removed from the drum and developed into a permanent record.

In investigating a water supply for waste, the first point to be considered is the pumpage or other source of supply to



Typical 24-hour record on 12″ district supply main. Light portion represents flow.

the reservoirs, and in the case of a pumped supply the error of the engine register due to slip, is often a very important item, especially in small plants where other type of pump than the crank and fly wheel outside packed pump is used. By means of pitometer measurements taken near the pumping station, either on the discharge or the suction lines, the exact slip of the pumps, and consequently the amount that should be deducted from the engine logs can easily be determined. At the same time it is well to take pitometer measurements at the top of the pumping mains, just before they enter the reservoir or standpipes, and by comparing these with the records taken at the foot of the main, the loss in the rising main can be accurately determined. In this way the presence of unknown connections to the rising main, open washouts, or leaky joints can be determined, and located by making further readings at different points on the rising main, and comparing these records with the engine logs.

The next step is to take readings or records for an extended period, of all water leaving the reservoir and entering the district to be investigated. The first deduction possible from these records will be that of the presence of leak in the reservoir, which can be readily determined by comparing these records with the engine log and reservoir levels. In the district I shall describe, a surplus of water over the actual pumpage was found, which led to the discovery of imperfectly closed gates between the water of the district and that of an adjoining higher pressure system.

Then, by considering the consumption curves as shown by these records, and considering the character and requirements of the district, the relative day and night flow can be translated into terms of legitimate use, intermittent waste and constant waste.

The third step, if the district supply records have shown a large unwarranted flow at night, or an excessively high per capita daily rate, is to subdivide the district and repeat the records until the wastage is in some measure localized. Then by setting the instrument at the head of a street and successively shutting off the house services until all that could affect

it are closed, any leaks in services or street mains can be located and checked, this process being continued street by street until all of the sub district is covered.

A preliminary survey on the lines above described, has just been completed of that section of the city supplied with water from the Bedford Reservoir, and the data and results obtained, together with some conclusions deduced therefrom, are embodied in the following tabulation:

1.	Area of district investigated	286 acres
2.	Population	27,241
3.	Total number of houses	3773
4.	Total number of services	2580
5.	Average population, per house	7.2
6.	Average population per service	10.5
7.	Number of meters in the district	1931
8.	Number of houses supplied through meters	2542
9.	Population supplied through meters	18,302
10.	Number of meters available for reading, and which were considered in this investigation	1767
11.	Percent of services metered	74.8%
12.	Percent metered and available	68.4%
13.	Population supplied through available meters	16,799
14.	Population per meter, through available meters	9.5
15.	Slip of pump, (by pitometer)	3.57%
16.	Loss in rising main, (by pitometer)	3.86%
17.	Average indicated gallons per day	4,120,502 gallons
18.	Less 7.43%, or gallons actually delivered at the head of rising main, per day	3,814,349 gallons
19.	Total water consumption of district, averaged during test, from pitometer records, per day	4,325,000 gallons

This average daily consumption, being greater than the pumpage shown for the district, indicated some connection between the Herron Hill and Bedford systems, which would permit the Herron Hill water, which is of higher pressure, to enter the Bedford system somewhere above the pitometers. On investigation this was found to be the case, two cross over

gates, one 6-inch and one 8-inch, being found open several turns each.

20. Minimum night flow, (midnight to 5 A. M.), as measured by pitometers, at a rate per 24 hours of.....3,050,000 gallons
21. Ratio of night flow to mean rate per day 70.5%
22. Measured by 1767 meters, per day.....1,901,512 gallons
23. Unmetered water, per day.....2,423,488 gallons
24. Per cent of total water metered 43.7%
25. Per cent of total water not metered 56.3%
26. Per cent of metered services found leaking 16.4%
27. Aggregate of leaks so located, per day ... 623,520 gallons
28. Ratio to total metered consumption 32.8%
29. Ratio to total water entering district 14.4%
30. If through 68.4% of the total services there flows 43.7% of the total water entering the district, through all the service pipes there should flow, at the same rate, 63.9% of the total water, or per day ..... 2,763,675 gallons..
31. Subtracting this from total entering district leaves a loss before reaching the service pipes, per day of..... 1,561,325 gallons
32. Per capita leakage before service pipes, or in street mains, defective valves, etc., is per day..... 57 gallons
33. If through 68.4% of the total services metered, leaks aggregating 14.4% of the total water entering district were found, there should be a total metered leak, at this rate, in all the services, per day of ..... 908,250 gallons
34. Per capita constant and preventable leak, through defective service pipes and house plumbing, per day ..... 33 gallons
35. Total use per capita per day ..... 158 gallons
36. Total per capita waste per day ..... 90 gallons

37. Ratio, total leak to total water 57.1%
38. Per capita use through meters per day ..... 113 gallons

NOTE.—Figures for the number of houses and the number of services in the district are approximate, and all figures deduced from these must be regarded in this light.

The work is now being followed up along the lines above laid out, by dividing the district up into sub districts, and making house to house inspections in those districts showing a high night use, together with street to street inspection for pipe leaks on such streets as show flow through the pipes after shutting off all known service pipes.

DISCUSSION.

F. Z. SCHELLENBERG, Member—What is the etymology of that word "Pitometer?"

J. D. UNDERWOOD—It was derived from the name of the man who discovered the Pitot tube.

K. A. MUELLENHOFF, Member—How accurate are these measurements?

J. D. UNDERWOOD—I think that 2% is about as close as you can get. I have checked the pitometer with meters, and with pumps in which I was sure there was little slip, and I found it came within 2%, one way or the other, but generally less.

The instrument that was used before the pitometer was invented was the Deacon Meter, which had to be attached in the same way that any meter would, and which necessitated shutting off the main. With the pitometer all that has to be done is to put a ferrule in the main, though it does require some little attention during the test, which usually covers a period of 24 hours for each record taken.

A. A. LANE, Member—I saw a water main taken up in Allegheny, the inside of which looked as if it had a growth of barnacles of an average thickness of an inch and a half. In such a case do you calculate the flow on the internal diameter of the pipe?

J. D. UNDERWOOD—By pushing the rod meter to the inside of the pipe we can measure the position of the top of the incrustation and then by pulling it back to the other side we can measure the true diameter of the pipe, and so make allowance for any growth in the interior of the pipe. I have found very old four inch pipes in the Bedford District which did not have more than 2½ inches of clear passage for water to go through.

A. STUCKI, Member—We all know that the velocity of water at the periphery is not as great as near the center, the outer sheets of water acting as a sort of antifriction layers, and I would like to know just where the greatest velocity of the water does occur.

J. D. UNDERWOOD—That depends on certain conditions in the pipe. For instance, in a pipe that is rising, the point of greatest velocity is generally slightly below the center of the pipe, and in a pipe that is falling it is slightly above. That is taken care of in my work by an operation called a pipe traverse, which is done by taking "U" tube deflections every inch or so across the pipe, and from these plotting a velocity curve, from which in turn a coefficient of velocity is obtained. By multiplying the results of the "record" by this coefficient, the difference in velocity between the center of the pipe and the periphery is taken care of. About 0.80 of the greatest velocity in the cross section is generally a pretty close approximation of the coefficient. I would like to say in connection with this, that no matter what the change in velocity, the coefficient of velocity, as above, is constant.

E. D. LELAND, Member—I would like to ask Mr. Underwood if he takes into consideration the actual diameter of the pipe in working out results wtih his formula.

J. D. UNDERWOOD—Yes, the only trouble of course is that we can't measure the diameter of the pipe accurately, we may strike the hump or the hollow of the incrustation, but at the point at which we take the readings the velocity takes the dimensions of the pipe.

A. STUCKI—The incrustations being heaviest at the bot-

tom, I suppose the proper place to tap a pipe is from the top, so as not to get a fictitious value for the cross sectional area.

J. D. UNDERWOOD—The pipe is almost always tapped from the top, but the incrustation is not much thicker at the bottom, it grows pretty generally around the pipe, with perhaps ⅛ inch extra thickness at the bottom of the pipe.

K. A. MUELLENHOFF—The question of the stopping of the excessive leaks is a very important one, especially for cities like New York where the water supply is short, and it may be interesting to state for comparison, that in European cities the amount of water used per capita is about one-half what it is in this country. In this city the water consumption is about 158 gallons per capita. The highest consumption I remember having read of in Europe is about 45 gallons per capita, and that is in Paris where they have a great number of boulevards and use a great amount of water for sprinkling purposes.

J. D. UNDERWOOD—In regard to the use of water in European cities compared with American cities, I would state that in the Metropolitan system in Massachusetts in the town of Malden, which is a city of perhaps 35,000, they have practically every service metered and they use about 50 gallons per capita per day, and that rate should obtain where every service is metered. If a man finds his plumbing leaking and has to pay for the leaking water, he will get it fixed very quickly.

K. A. MUELLENHOFF—One other thing may account for the greater amount of water used and that is the far greater number of bath room installations here.

J. D. UNDERWOOD—The legitimate use of water for bath room purposes or any domestic purpose does not really amount to very much. It is where people allow the water to run in order to cool the water and forget to shut it off for a few minutes. I was watching a meter the other day when a woman went to wash her hands, and the water she drew to wash her hands registered eighteen gallons on that meter That was simply through running the water through instead of filling the bowl.

G. E. Flanagan, Member—It is customary to go to the stationary wash stand and never put the stopper in and use the running water. If it takes three minutes to wash your face and hands the water is running three minutes. That is where more of it goes than ever enters the bath tub.

F. Z. Schellenberg—The closets in public places that run water all the time waste a great deal.

J. D. Underwood—In the closets in the hill district many have a faucet directly under the seat which is allowed to run continuously. A great many have spring connections that are supposed to flush when one is sitting on the seat and to cut off when they rise, but it seldom works after the first two or three months. The pressure is pretty high there, running from 30 pounds at the reservoir to 115 at the lower side of the district, and even having put in new plumbing the water hammer will knock it to pieces quickly.

F. Z. Schellenberg—There ought to be an adjustment to the service of a house to let the amount of water enter that belongs legitimately to it.

J. D. Underwood—There has been some talk lately of putting on pressure reducers to cut down the pressure to about 50 pounds, but it is possible that some of the mains are so encrusted, that such a reduction in pressure would diminish the supply to too small a quantity.

H. C. Babbitt, Member—Do you know of any modification of the pitometer for measuring the flow of gases?

E. D. Leland—The Pitot tube is frequently used for gas measurements, but in that case, the static pressure must be taken into account.

Measurements thus obtained agree very closely with results derived by the formula for the flow of gas in pipes, as shown by difference in pressure between two given points. This formula has been tested and checked in Indiana by the actual performance of positive displacement gas compressors delivering into long pipe lines, and found to be fairly reliable.

The close agreement of the various methods gives confidence in the Pitot tube readings, and in ordinary practice no distinction is made between it and other reliable methods of gas measurement.

J. D. UNDERWOOD—Do you use any especial specific gravity of liquid and do you use a "U" tube connection?

E. D. LELAND—Yes, we use oil of a standard specific gravity, and also a "U" tube which we check up at frequent intervals. We do not use the Pitot tube for very high pressure. For high velocities it would be necessary to use mercury.

L. C. MOORE, Member—Is it not a fact that they pretty nearly know what the consumption of water should be in a city like this, and if so what effect would metering of water for house service have on the amount pumped daily?

J. D. UNDERWOOD—The approximate correct consumption or the reasonable consumption, is very easily arrived at, but there are a great many manufacturing plants that use large quantities of water. For instance, taking the per capita used for the whole city at nearly 250 gallons, that of course allows for all the manufacturers who use city water, probably a large percentage. But this district I have investigated does not have any manufacturing service.

L. C. MOORE—Suppose the city should undertake to meter all the water that is used for private consumption, outside of fires. Then what would happen, what would be the percentage of reduction from the 250 gallons per capita?

J. D. UNDERWOOD—With the city entirely metered I think the consumption of water would be cut down practically one-half. But in hardly any water plant can they account for more than 65 to 70% of the water they pump, even where all their service pipes are metered.

L. C. MOORE—Then if the city were metered properly we would save the cost of pumping 35% of the water we are now pumping?

J. D. UNDERWOOD—Yes. However, the direct fuel cost of water is not the great item. The maintenance of the pipe

lines and the extensions are the principal items. The fuel cost is somewhere between $5.00 and $6.00 per million gallons to pump it to high pressure, and for hill pressure, where it has to be repumped it costs about as much again. The city is pumping about 70,000,000 gallons a day and you might cut that down to 55,000,000, and yet you would not save so great an amount of money because your pipe line maintenance would be just as great as it ever was and your extensions would be practically as great. The point is that if it could be cut down in that way it would make the present pumping stations, the present sizes of pipe lines and the filtration plant sufficient for a good many years to come.

W. O. Brosius, Member—What proportion of the water is used for manufacturing purposes?

J. D. Underwood—I have not gone into that, and I can only make a comparison of the approximate per capita of the entire city, at 250 gallons a day, and 158 gallons for this district, which does not contain manufacturing plants.

W. M. Brosius—The manufacturing supply is not metered in any way?

J. D. Underwood—Yes, a great many are metered. It is hard to get really accurate figures because I should think fully one-half the factories in town have their own wells and pump their own water, using the city connections only as an emergency supply. Practically every building of any size in New York has roof tanks. There are comparatively few here on account of the high pressure. That in New York is a very fruitful cause of waste because the tanks are almost all provided with ball cocks that don't work and consequently the tanks keep on filling up and overflowing, whereas here we have very little of that. I have not found a single one in this district of 280 acres.

PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

Vol. XXII JANUARY, 1907 No. 10

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

*MATERIALS AND PROPERTIES OF WROUGHT PIPE.

†F. N. SPELLER.
Member.

It is not within the scope of this paper to discuss in detail the processes of manufacture of welded pipe, nor would there be time: that portion of the subject has been fully treated in papers previously read before this Society.‡ The object is to draw attention more particularly to certain characteristics possessed by the metals used in the manufacture of modern welded pipe and certain qualities which have considerably widened the field of use for tubular goods.

Before considering the properties of the materials, some lantern slides will be shown illustrating the chief operations involved in the metallurgy of pipe material, and the manufacture of welded tubes and pipe. The photographs were taken in the works of the National Tube Company, and show examples of the old methods of working, as well as the extensive modern mills which are now taking their place.

For years wrought iron was the only material available for this purpose, but within the past fifteen years the making

* Meeting of the Society, Nov. 20, 1906.

† National Tube Co., Frick Bldg., Pittsburgh, Pa.

‡ V. 4, P. 6-12, 25-33. V. 19, P. 796-834.

of weld-steel has become a special branch of the steel industry and furnishes a material having many advantages for mechanical welding operations.

Enumerating the chief metallurgical processes in historical order, we have, first;—the making of charcoal iron from charcoal pig iron: The silicon and manganese are first almost completely removed by melting the pig iron in the refinery or

FIG. 1. Charging double-length butt weld furnace.

run out fire. The plate metal from this furnace is further refined in the "knobbling fire," using charcoal for fuel. This is interesting as being a slightly modified form of the furnace used in the early days of the iron industry for the making of wrought iron and steel direct from the ore. The bloom produced is repeatedly heated and hammered, and finally rolled into a bar,

which is re-piled four or five high, heated to a welding temperature, and rolled into a plate, preferably in a continuous mill. This is the finest wrought iron which can be made, and is still used in the tube works, although in decreasing amounts, principally in the manufacture of boiler tubes. The following average analyses of several heats will indicate the progress of the refining at each operation:

	Total Carbon	Manganese	Silicon	Phosphorous	Sulphur	Oxides and Cinder
Pig Iron	3.85%	.980	.940	.086	.025	....
Refinery Metal	3.50 (Comb)	Trace	.210	.070	.024	....
Finished Plate	Trace	Trace	.014	.024	.014	.92

The puddling furnace furnishes wrought iron of a much coarser grade better adapted for standard pipe, having the following average composition:

Silicon	.100
Phosphorus	.220
Sulphide	.020
Manganese	Trace
Carbon	"
Oxides and Slag	2%

The strenuous nature of the work is well known to anyone who has watched a puddler around his furnace. An hour and a half's operation in the furnace reduces the charge of pig iron to a 500-lb. mass of refined iron of pasty consistency, which is divided into two balls to facilitate handling. The product is unfortunately hard to regulate in quality on account of:

1°. Irregularities in composition of pig iron used;

2°. The small quantity made in one heat;

3°. The amount of personal attention and skill required on the part of the puddler and the large personal equation thereby introduced.

Iron made by this process to-day is rendered still more unreliable by the practice of intermixing steel scrap of various composition.

By carrying the Bessemer process to the limit of refining, and treating the metal so as to give the best results in welding

a refined iron is produced practically uniform in quality, which will roll into a plate with a true edge, a very desirable condition for good results in the pipe mills. To obtain the best results it is necessary to manufacture "pipe steel" on a scale sufficiently large to take the full capacity of a steel plant. Under these conditions it is probably safe to say that a uni-

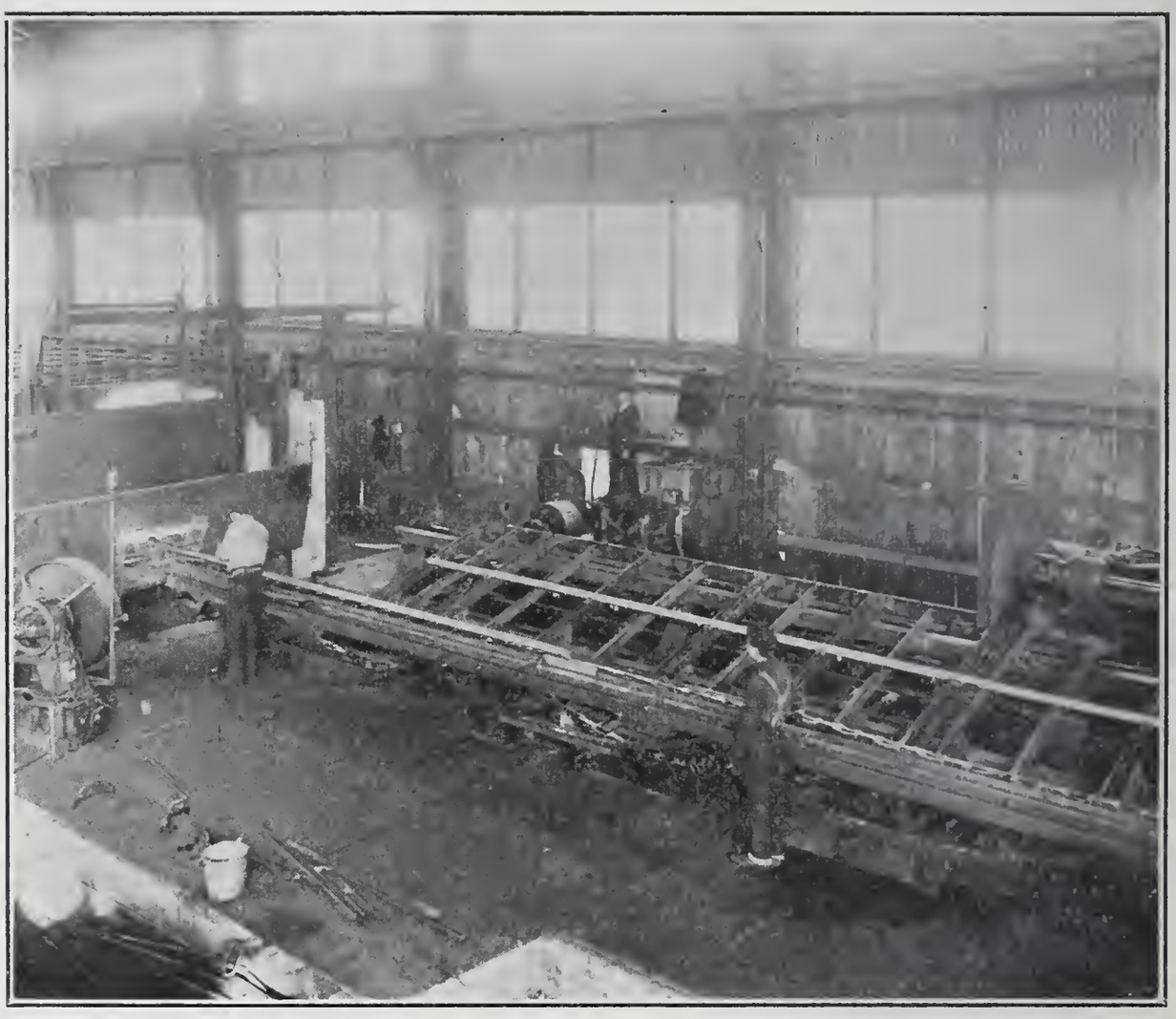


FIG. 2. Drawing butt-weld pipe.

formity of product is obtained unequalled by any other class of steel manufactured on this scale. A smaller proportion of pipe steel is made by the Basic Open Hearth process, but the easy control and continuous supply of uniformly very low carbon steel which can be had from a Bessemer plant running in conjunction with pipe and tube mills, and the satisfactory nature of the product, has caused the Bessemer process to become

generally used for this class of work. The higher phosphorus and sulphur contents are no objection in welded pipe where the quantity of metal used is so greatly in excess of what strength requires, and moreover these elements become a necessity if the pipe is to be tolerably easy to thread.

Pipe steel welds with greater ease and with much less loss on account of blisters and laminations than wrought iron.

A type of mill for rolling skelp has been shown, also photographs of the latest modern butt and lap weld mills, the former making 40 foot lengths up to 3 inches in diameter, and the latter welding pipe up to 36 inches in diameter.

GROWTH OF TUBE AND PIPE INDUSTRY.

The production of welded tubes and pipe has almost doubled in tonnage since 1899. During this period the process of making pipe steel and mechanical welding by the butt and lap weld process has been much improved, giving a more uniform product and at the same time reducing costs all round. The introduction of pipe steel has apparently had somewhat the same influence in expanding the field of use for tubular goods as the advent of structural steel exercised on the production of materials of construction formerly made of wrought iron. Last year (1905) the production of tubular goods in the United States (1,435,995 tons) nearly equalled that of rolled structural shapes (1,660,519 tons) not including plate. The demand this year promises to reach 1,700,000 tons.

The generally good welding quality of wrought iron enabled it to maintain its position for the manufacture of pipe years after it had been displaced by steel as a material for general engineering construction. In 1890 about 3% of the welded pipe was made of steel; in 1905 this had increased to 70%, and it is estimated that steel pipe will constitute 80% of the output for 1906. Besides the general use of pipe in steam, water, gas and oil lines, which consumes the larger part of the tonnage, increased amounts are being used for trolley poles, electric conduits, bedstead construction and for other special purposes.

Among the special uses to which steel pipe lends itself, the catenary system of trolley suspension might be referred to. Large quantities of the small sizes of extra strong pipe are used in making the light triangular frames from which the live wire is suspended in high speed electric railroad construction. The joints are either threaded, or flattened and pinned togeth-

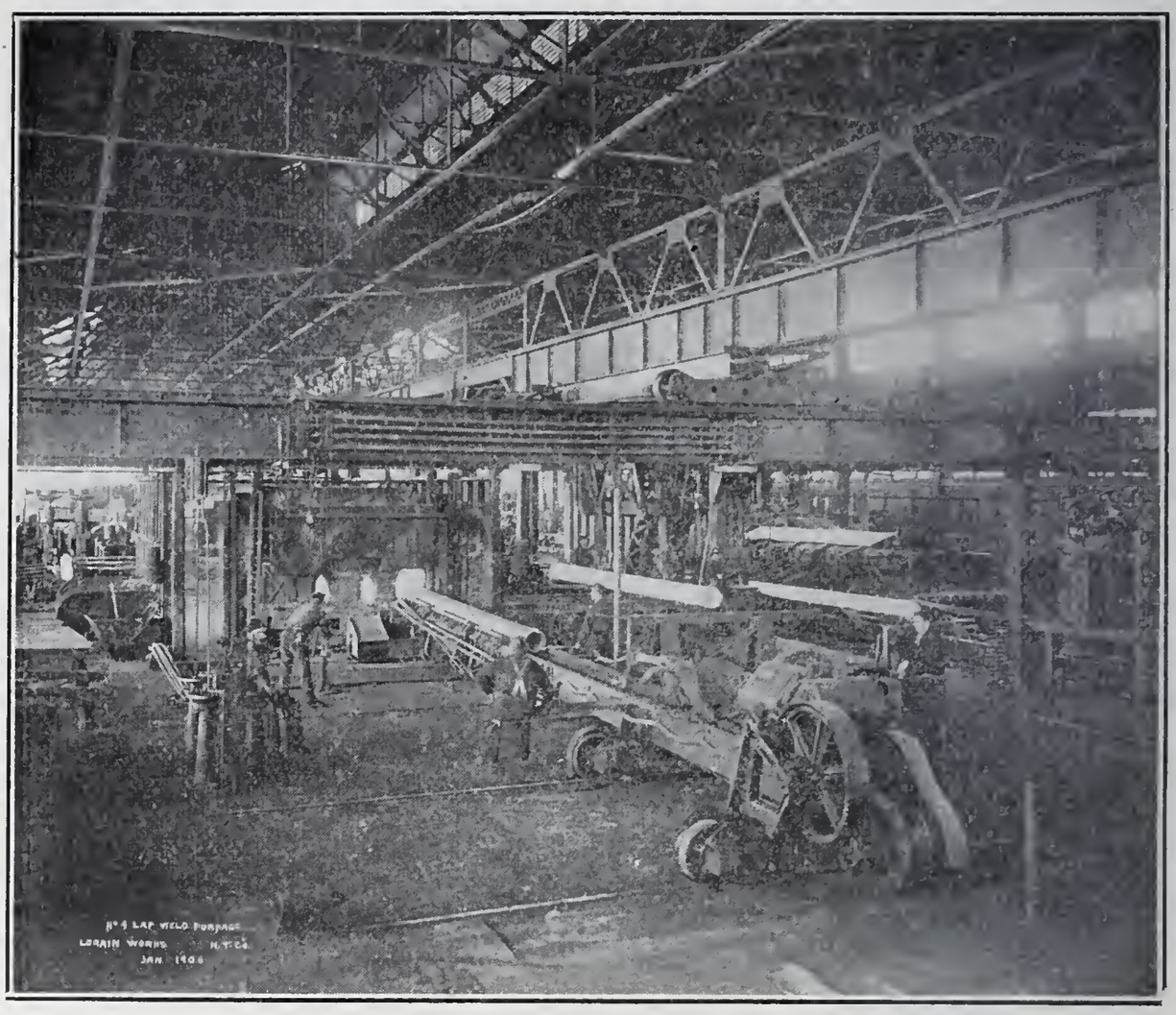


FIG. 3. Charging end of lap-weld furnace, showing also bending of plate.

er. Steel pipe combines a maximum strength with a minimum weight, which is very desirable for such work. Wherever pipe has to be bent or worked either hot or cold the modern material has a decided advantage.

In the California field a quantity of steel pipe has been rifled, the object being to cause the viscous oil intermixed with a small per cent of water to whirl as it moves rapidly through

the pipe, thus when a sufficient velocity is attained, a layer of water flows between the oil and the pipe reducing the friction in the line.

It has been found quite practicable to roll spiral corrugations $\frac{3}{32}''$ deep in the surface of the pipe by means of six wheels set equidistant around the circumference and slightly inclined

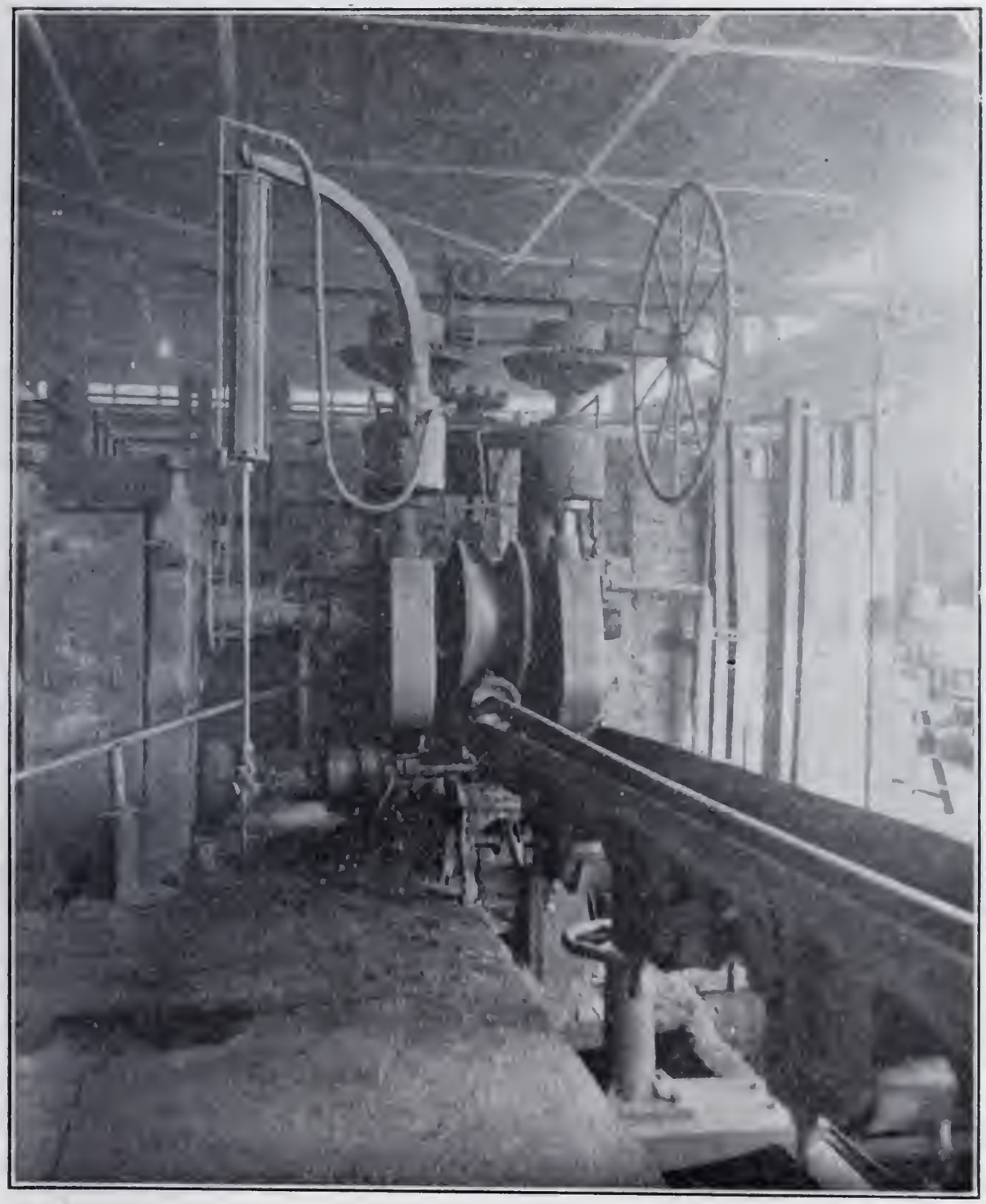


FIG. 4. Lap-welding rolls.

to the axis of the pipe, so as to make a complete revolution on the surface of the pipe every 10 feet. The material appears to stand this treatment cold without difficulty.

It might be well to refer here to the heat treatment necessary to anneal pipe steel. The heat required to weld iron or steel produces a larger grain in the metal. For most purposes this does no harm and steel pipe unannealed will stand severe

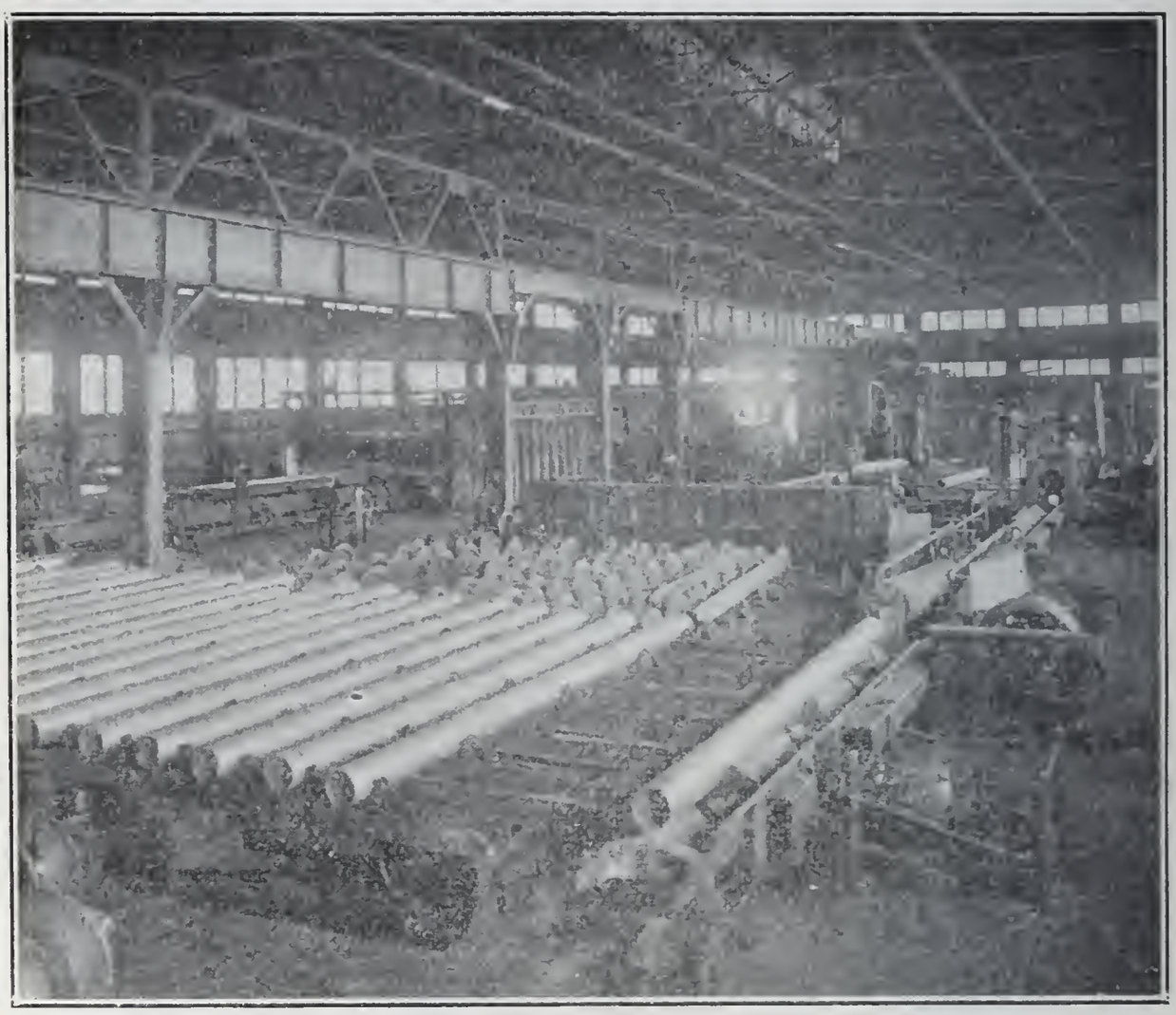


FIG. 5. General arrangement finished end lap-weld furnace.

cold bending without fracture, having an elongation of 20 to 22% in this state, but where the pipe has to be worked hot it is advantageous to first heat to a full orange (above the critical range or 900 degrees C.) for a few minutes and allow it to cool in the air. This will completely remove all possible effect of overheating by refining the grain, and will enable the metal

to be worked without danger from red shortness. Tubes or pipe will also stand more cold working without fatigue if so annealed.

PRINCIPAL PHYSICAL CHARACTERISTICS OF PIPE MATERIALS.

From the manufacturing standpoint, the superior welding quality, uniformity and lower cost of pipe steel are the deter-

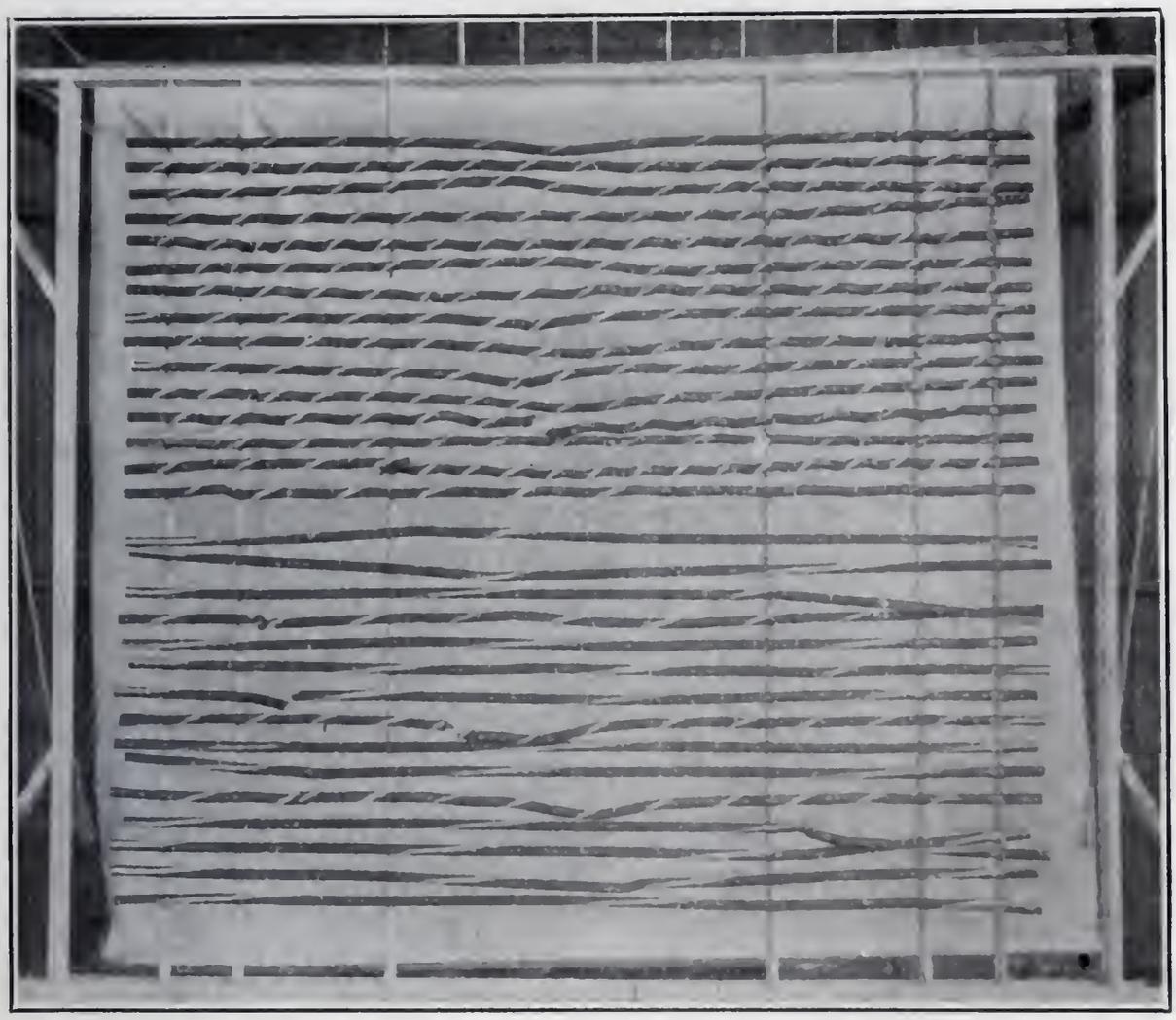


FIG. 6. Twisting tests.

mining qualities. These cannot, however, be obtained to good advantage without working on a large scale and manufacturing this grade of steel exclusively. The tensile strength of pipe steel pulled transversely is about double that of wrought iron, hence the welded seam might be expected to be proportionately strong. This has been shown to be true by experi-

ments on 2-inch butt welded pipe. The average strength of the weld was thus found to be 70-72% of the strength of the metal transversely in each case, and the steel weld proved to be twice as strong as the wrought iron. Bursting tests on wrought iron and steel butt welded pipe confirm these conclusions. The strength of the seams was compared by twisting pieces 8 feet long until they failed. The following results were obtained on three sizes of standard pipe, the appearance of the pieces after testing can be judged by Fig. 6 shown on preceding page.

TABLE I.

Twisting Tests on Butt-welded Pipe.*

SUMMARY.

Size	Material	Make	Wt. per ft. lbs.	Variation from card wt. %	Max. 3 foot Low	Pull on lever High	Lbs. av.	No. of turns in 6 ft. before failure	% failed in weld
½″	Steel	N. T. Co.	.816	-2.2	90	120	109	15	0
"	Iron	1	.803	-4.2	40	98	68½	4½	73
"	Iron	2	.792	-5.2	20	113	81	5¾	66
"	Iron	3	.842	+0.6	50	85	65	2½	100
¾″	Steel	N. T. Co.	1.082	-2.9	160	185	172	8	13
"	Iron	1	1.079	-3.1	15	160	125	3¾	57
"	Iron	2	1.127	+1.0	80	176	136	3½	66
"	Iron	3	1.104	-1.0	50	160	107	2½	90
1″	Steel	N. T. Co.	1.658	-0.7	180	340	300	5½	13
"	Iron	1	1.593	-4.4	220	292	256	4½	46
"	Iron	2	1.616	-3.1	170	300	250	3⅓	33
"	Iron	3	1.620	-2.8	100	320	258	2¾	66

* From T. N. Thompson's paper—"Power required to Thread Twist and Split Wrought Iron and Weld Steel Pipes," before Amer. Soc. of Heating and Ventilating Engineers, Jan. 1906.

Pipe steel finishes with a smoother surface than wrought iron, which for some purposes is very desirable.

A list of the physical properties of steel pipe would not be complete without referring to the exhaustive series of tests made on the National Tube Company's lap weld steel pipe by Prof. R. T. Stewart, to determine the collapsing pressures. This work occupied one to six men four years and involved the collapsing of nearly four hundred pieces of pipe, 3 to 10 in. in diameter, mostly 20 feet in length.

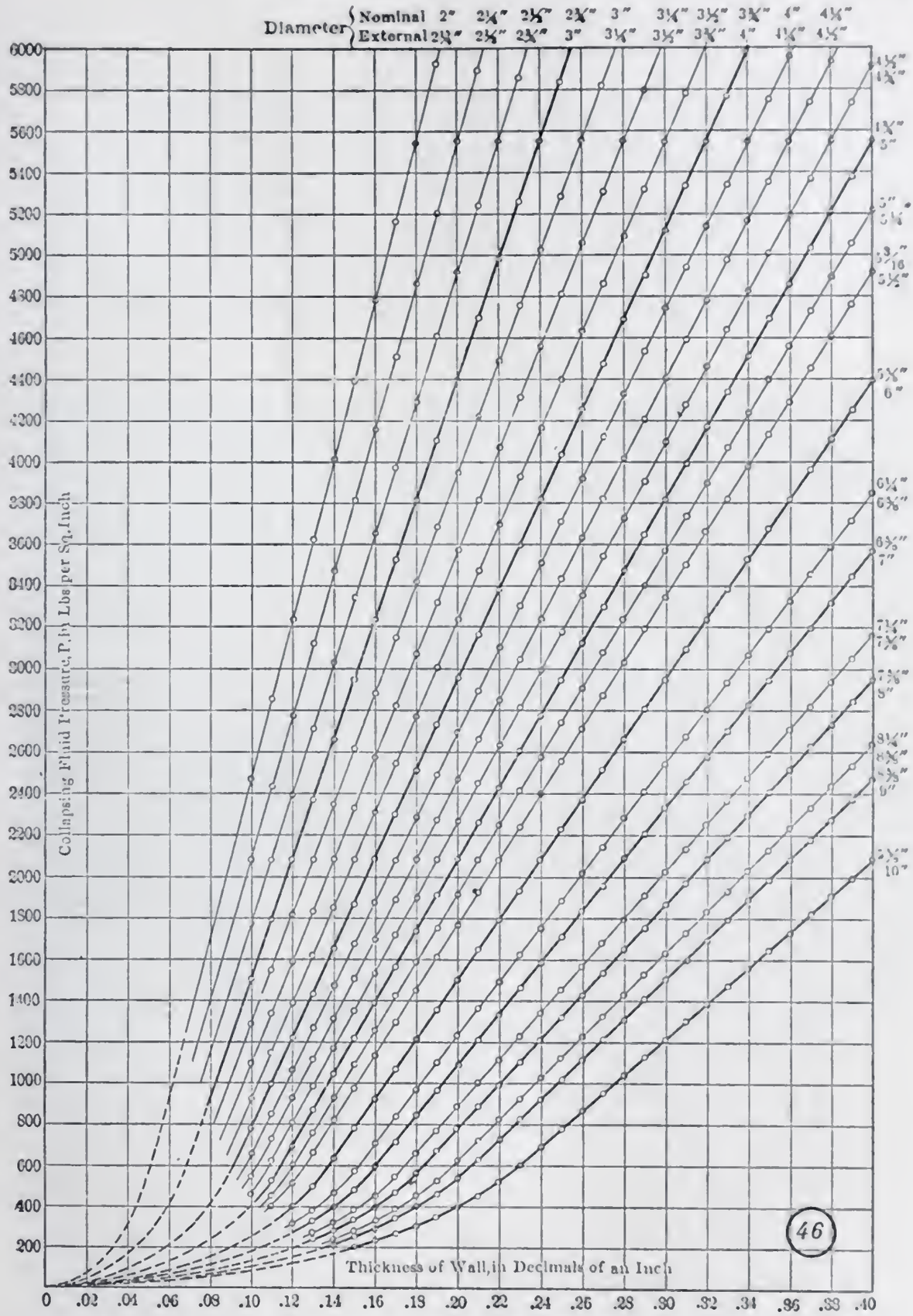


Fig. 7. Diagram of collapsing pressures.

Fig. 7 gives the collapsing pressure for all sizes and gauges from 3 to 10 inches diameter, and for all lengths over six times the diameter. Further details may be had by reference to Prof. Stewart's papers in Trans. of Am. Soc. of M. E. for 1906.

THREADING PIPE.

Steel pipe has been objected to by some, chiefly on account of the fact that it is somewhat harder to thread with the poor dies with which many threading shops are equipped, and which are too commonly sold to the trade. It is to be expected that a practically pure iron will offer more resistance to a blunt and improperly shaped die, than will a metal like pud-

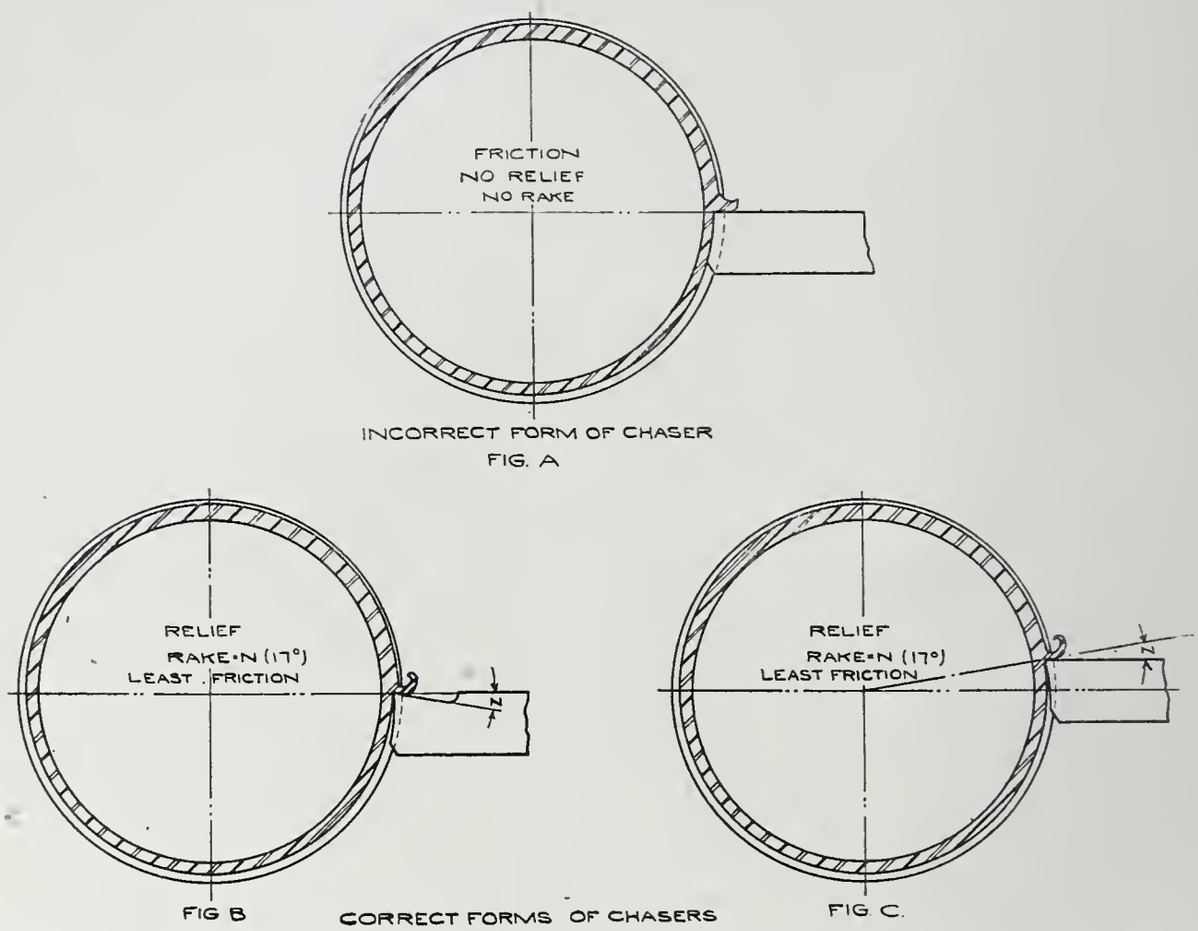


DIAGRAM SHOWING CORRECT AND INCORRECT FORMS OF THREADING DIE.

FIG. 8.

dled iron, in which are intermixed layers and strings of cinder amounting to 2 or 3%. The power required to thread with a die shaped as shown diagrammatically in Fig. 8-A will be approximately proportional to the tenacity of the metal. By grinding the chasers as shown in Fig. 8-B or C and providing relief, so that the heel does not drag on the work, the difference in power required to thread iron and steel disappears and

much better results are obtained with less wear and tear on the dies.

Considerable unnecessary trouble has been caused through die makers not recognizing the importance of these points, especially to the small operator depending on hand power. It may seem to some a rather elementary point to emphasize before this Society, but we even now occasionally hear from large well equipped shops up to date with nearly all mod-

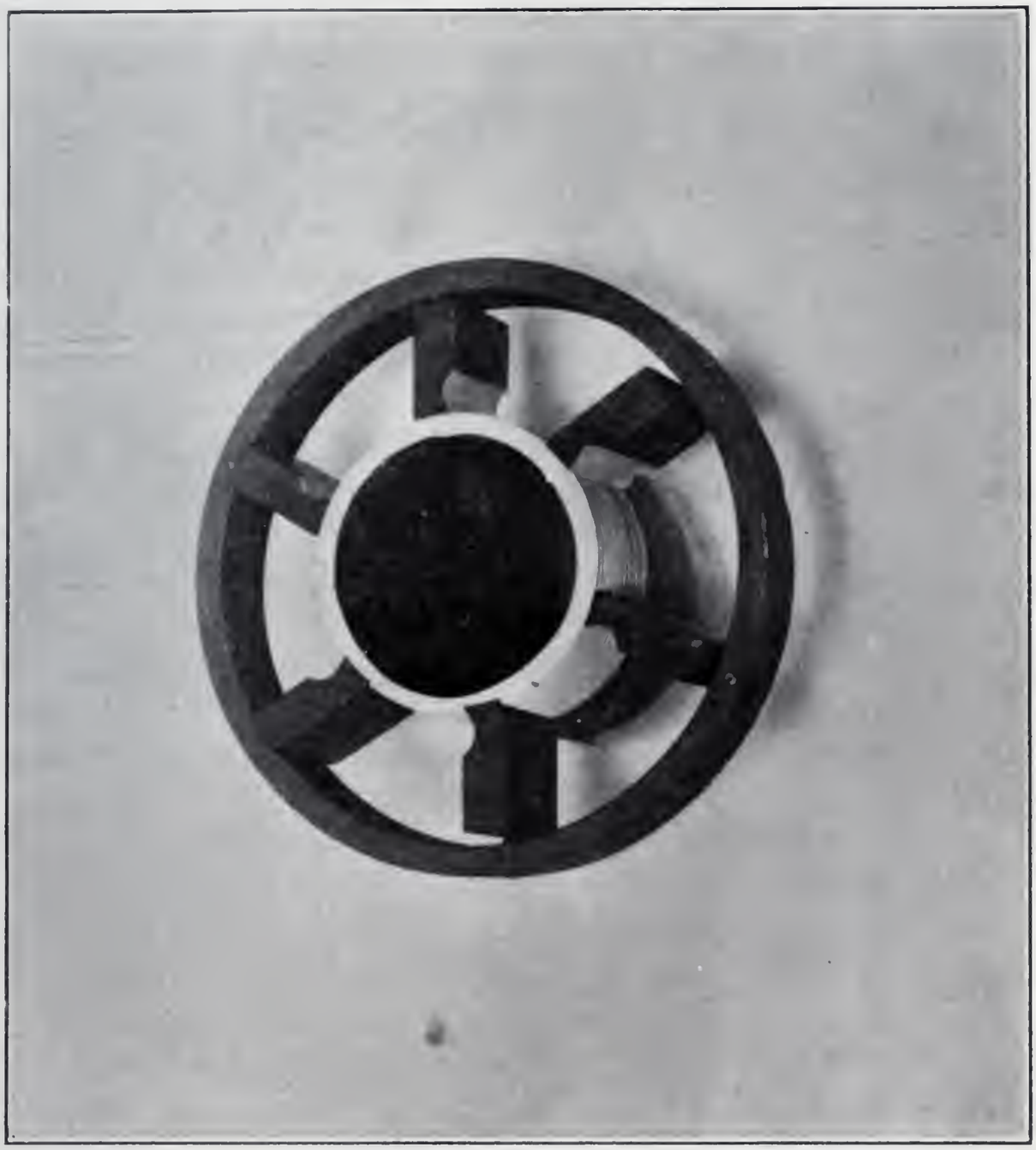


FIG. 9. Chasers properly ground for threading steel pipe.

ern improvements, yet ten or fifteen years behind in their die equipment. It is not surprising that some have preferred wrought iron where much hand threading and cutting has to be done, as it is only within the past year or two that the much needed improvement has been introduced by certain makers of standard hand dies.

CORROSION OF IRON AND STEEL.

This is a question which has brought forth many opinions, but in most cases with little practical evidence. After investigating closely many cases which have come under my observation during the past two years, where the two materials were put in service together and subject to the same conditions, I have never yet found any decided difference. The impression which exists in some minds that wrought iron pipe is much superior to steel in durability, may have originated in comparisons made years ago when the practice of making sound low carbon steel was probably not so well understood as it is to-day, or it may have been a mistaken identity for we frequently find iron mistaken for steel, especially if it happens for some cause or other to be pitted, but in most cases the idea has apparently been spread by hearsay and accepted without investigation.

In view of the inherent differences between iron and steel made for various uses, it would seem safer to compare each class by itself, i. e. wire, sheet, pipe, etc., each under the conditions of service to which they are subjected.

The essential conditions of corrosion, air, water and carbonic acid, are easily duplicated in the laboratory, but in practice corrosion is accelerated by presence of suphurous and other solutions, stray electric currents, heat and numerous other influences difficult to trace.

It will be conceded that such conditions tending to seriously affect corrosion, are rapidly on the increase, especially in and near the great centers of population. Hence we should be slow to draw conclusions from the statement that steel

does not last now-a-days as it did 15 or 20 years ago. Whatever was the relative standing of the two materials years ago (and opinions differ widely) what we are more concerned with is how do they stand to-day, and how can they be best protected from corrosion? Laboratory results, while open to criticism, as not truly representing actual conditions in the field, are valuable as indicating the relative standing of a number of samples under conditions known to be uniform—something difficult to be sure of in service tests. The writer has in his tests lately, used a 5% hot solution of brine through which a continuous flow of air is pumped. One reason for adopting this solution is that a number of tests are on record which indicate that steel in general seems to be somewhat more susceptible to this environment than wrought iron, and further that the loss is quite considerable in a reasonable time (about 1-10 gram. per sq. in. per month). A number of average results on pipe materials are given in Table II., comparison being made with good wrought iron as a standard.

There are two possible ways of protecting steel: 1st, by use of efficient protective coatings; 2nd, by treatment of the metal in the course of manufacture. Experiments have been under way for some time at the works of the National Tube Company with the object of increasing the durability of pipe steel. As a first step in this direction a process has been developed which after a year and a half's trial has given results showing a decided benefit to the steel, especially in the uniformity with which it corrodes. The treatment consists in a mechanical working or kneading of the metal which tends to produce greater uniformity and improve the quality and texture of the steel. Doubtless much of the steel does not need this treatment, but in such cases it does no harm, and on the whole raises the average standard of the output. Tests marked No. 4, 5, and 6 were made on this steel.

It has been recognized that service tests must be made before any certain conclusion can be reached. A number of such tests have been made on this steel pipe in sulphurous air, salt water, and mine water during the past year, precau-

TABLE II.

Average results of recent comparative tests on corrosion of wrought iron and pipe steel.

(Losses per unit of surface exposed compared with puddled iron as 100.)

Conditions of Test	Authority	Duration of Test	Charcoal Iron	Puddled Iron	Pipe Steel	Test Started
1. Aerated Distilled Water. Normal Temp.	U. S. Navy Dept.	64 weeks	100		94 5	1901
2. Sea Water. Normal Temp.	H. M. Howe	2 years		100	119	1897
3. Aerated Brine. Normal Temp.	Lab'ry Nat'l Tube	6 months		100	106	1904
4. Aerated Water. 180 deg. F.	Lab'ry Nat'l Tube	3 months		100	90.6	1905
5. Aerated Brine. 180 deg. F.	Lab'ry Nat'l Tube	3 months	80	100	75.3	1906
6. Aerated Sea Water. 180 deg. F.	Howe	3 months	94.4	100	94.2	1906

tions being taken to have an equal number of pieces of "genuine" wrought iron pipe alongside under the same conditions. One or two tests which have been made in this way in suphurous mine water are shown to illustrate the comparative uniform corrosion of the steel. The results so far have shown the steel so treated without exception to be at least the equal and generally decidedly superior to wrought iron.

DISCUSSION.

S. B. Ely, Member—Regarding the corrosion of iron and steel, I know in the case of sheets, that you can find any number of iron roofs in the country that have been in service from 25 to 50 years. I have never been able to find any steel roofs of that kind. And it is pretty good proof that the old iron, whatever it was, seemed to resist corrosion. And I know to-day that in the case of sheets, steel will not last nearly as long as iron sheets. I have thought that the presence of manganese had something to do with it. While I do not doubt the statements regarding pipe, I would like to know why there is such a difference between pipe and sheets in their rusting qualities.

K. F. Stahl, Member—I have noticed the same in our works, and I claim that manganese is to blame for the corrosion of steel sheets, therefore, I would like to ask Mr. Speller what the percentage of manganese is in his special pipe steel?

F. N. Speller—Before answering I would like to ask the gentlemen whether they have ever seen an iron and a steel one, unprotected, exposed side by side to the weather?

S. B. Ely—I do not know that I have ever seen them side by side. At the Wood plant at McKeesport they make both iron and steel sheets and the iron will last twice as long as the steel.

F. N. Speller—Do they put them in without any protective coating?

S. B. Ely—No.

F. N. Speller—That is the point. I believe tests are now being made where the two are exposed unpainted and very little difference is to be seen between the iron and the steel. At the same time some coarse grades of wrought iron roofing sheets appear to outlast steel roofing sheets in service. The explanation seems to be that this wrought iron has a rougher surface than steel which enables the paint to adhere more tenaciously.

The manganese in steel runs 3-10%. I do not believe that has anything to do with corrosion, for we have any number of tests of charcoal iron both in service and in the laboratory which show that it will pit more than pipe steel; and charcoal iron does not carry any manganese. We made a number of tests along that line by tubing one side of a boiler with charcoal iron and the other side with steel. And on the whole we found more cases of pitting among the charcoal iron tubes than the steel. There must be some other explanation for pitting. It is probably more often caused by external influences.

K. F. Stahl—What called my attention to the rapid corrosion of steel was a change we made about 10 years ago. We extended a building and used the old sheets which had been in use for eight or nine years on the side of the old building, on the side which we extended. On the *ends* we used new steel sheets; and I found after 4 or 5 years the steel sheets were considerably corroded, while the old iron sheets were still good. The steel was not bought painted, but we painted it well ourselves. When we buy corrugated sheets I specify that the manganese shall not be above 1-10%. There are always objections when the specifications go out, but we insist on them and several years ago rejected a whole car load of corrugated iron because the manganese was too high. The sheets we are getting now stand all right. The steel that we were getting in 1895 to 1898 is practically all gone while some of the old iron that has been on at least fifteen years is still good.

H. C. Cronemeyer, Member—This question of the more rapid corrosion of steel than wrought iron is very important in the tin plate industry too. It is almost universally claimed that the old tin roofing stood three or four times as long as the present roofing tin which is made out of steel. I am not a chemist and I do not know whether it is right or not, but in explanation of that they say that small particles of slag which are not thoroughly worked out in the puddling process protect the iron. I would like to ask Mr. Speller why it is that

while you make steel pipe you make the couplings out of iron?

F. N. SPELLER—The sockets have to be tapped and it is somewhat easier to tap the iron. But the main reason for using wrought iron is that a steel coupling galls the thread on a steel pipe so that it cannot be unscrewed without stripping the threads. It has often been useful to have an iron coupling to refer to in cases of corrosion. The iron of course has the advantage in that it is hammered in welding and gets a good deal more work than the pipe material. By comparing the effect on the coupling and the adjoining pipe a practical comparison of the two materials can be made. I have never yet heard of a case where there was very much difference in corrosion, and I have examined a great many.

S. B. ELY—Is there any truth in the statement that slag in iron prevents it rusting? Isn't it possible that pipe has to be made to meet certain physical conditions as to strength, etc., to get which the iron pipe has to be hammered until nearly all the slag is out. Whereas, in the case of a sheet there are no physical conditions of that sort: a good surface being about the only requirement.

L. A. STARRETT, Member—Owing to the larger number of chemical industries, there is a greater percentage of acids, alkalis, and other deleterious vapors in the air, than there was 10 years ago. Does not that affect the life of tin and sheet iron?

H. C. BABBITT, Member—A prominent tinner in this city only a few weeks ago speaking in regard to the relative merits of tin plate of iron or of steel, said that he had to repatch the steel plate three or four times while the iron plate remained good.

F. N. SPELLER—How old were the iron plates?

H. C. BABBITT—In some cases 25 to 40 years.

F. N. SPELLER—It has been stated on authority that practically all the so-called "charcoal iron" plate received from Wales in the last 25 years is open hearth steel. (A late U. S.

consular report states that the manufacture of charcoal iron has all but died out in Wales.)

H. C. Babbitt—I know that is not so now, and they must have known how to get low carbon and manganese a great deal better than we did 25 years ago.

K. F. Stahl—That would confirm my point that it is the manganese that is to blame for the corrosion. But after the black eye steel did get, I wish to say something in its favor. For the older tank cars made for transporting Sulphuric acid, twenty years ago, we used iron. We were at first afraid to change to steel as we did not know much about the action of sulphuric acid on steel. Now we have quite a number of cars with steel tanks that have run probably twelve years, and on examining them I found that the action of the acid on iron tanks, of which we have still a few, was much less uniform than on the steel. That is, there were streaks all through the plate that look somewhat like the corrugated rubber matting on the floor, while the steel tanks wear almost uniform, and are nearly smooth inside. This confirms the statement as to the pipe in mines, that it will stand acid as well or may be better than iron.

F. N. Speller—To illustrate that point I would like to pass around a few plates from one of our tests, to illustrate the effect of air and salt water on iron and steel. They do not need any labels; the uniformity of the steel is quite marked, while the wrought iron is much more pitted.

Morris Knowles, Member—One thing that particularly interested me was the rifled pipe. I would like to ask about what increase there is for ordinary pipe sizes, in cost where it is rifled. Another question: Has this ever been used for the carrying of any other combined liquid than oil and water? I have in mind the carrying of water and sand together.

F. N. Speller—I cannot say anything about cost; as far as we are concerned it is in an experimental state. As to water and sand I am inclined to think that it would work the other

way, the heavier material being thrown toward the outside—that is, the sand.

MORRIS KNOWLES—In carrying water and sand the sand generally segregates. It has been thought to obviate this by introducing spiral blades every few hundred feet and by stirring up the sand enabling it to be carried on further. I thought possibly the rifling of the pipe might have a similar effect.

EDMUND YARDLEY, Member—I would like to ask if these pipes are fit for inside plumbing use? Do they fail at the weld after a little time from corrosion?

F. N. SPELLER—It all depends on what the conditions are in the building. We feel quite confident in saying that the steel of to-day is somewhat better than wrought iron for that purpose. Iron and steel will always corrode. You cannot entirely prevent corrosion by any treatment of the material. In my experience pipe does not corrode at the weld more than at other places.

T. D. LYNCH, Member—How will butt-weld bend as compared with lap-weld?

F. N. SPELLER—I might answer that question by simply referring to the fact that large quantities of butt-weld pipe are used for electric conduits, coils and a number of other uses. If the pipe is placed with the weld on the side there is very little danger of opening the seam in bending. Large manufacturers of electric conduits use steel butt welded pipe exclusively, state that their loss runs about 2-10% and most of this material is bent cold. They use pipe as small as ⅜ inch bent to a radius of 4 inches.

J. L. KLINDWORTH, Member—I would like to ask what is the largest diameter of 40 foot lengths of pipes that is manufactured to-day.

F. N. SPELLER—Three inches.

RICHARD HIRSCH, Member—Does galvanizing have any effect on the life?

F. N. SPELLER—Yes, galvanizing increases the life very

materially. How much I could not say. The environment has every thing to do with it.

RICHARD HIRSCH, Member—Is it galvanized on the inside thoroughly?

F. N. SPELLER—The inside is coated with zinc under the same conditions as the outside.

RICHARD HIRSCH—Is it galvanized before it is threaded or after?

F. N. SPELLER—Pipe is galvanized before being threaded in most cases.

EDMUND YARDLEY—Do you consider galvanizing the best protection?

F. N. SPELLER—It is probably the best protection at present.

G. E. FLANAGAN—I would like to ask Mr. Speller something as to the method of rifling the pipe?

F. N. SPELLER—There is a head with six little wheels ranged at equal distances around the surface of the pipe and these are controlled by set screws, these wheels are set at a slight angle to the axis of the pipe, thus controlling the course of the rifle. The pipe is drawn through and the depth of the rifling is controlled by the pressure on the wheels. It may be done either cold or hot.

*OUR COAL.

†F. Z. SCHELLENBERG.
Member.

The United States has produced 6,000 million tons of coal, and the annual rate now is 400 millions, against 200 millions in 1897 and 100 millions in 1882.

Besides our annual production of 80 million tons of Pennsylvania anthracite we get 200 million tons of bituminous coal from Pennsylvania and the adjoining States of Ohio, West Virginia and Maryland; the sixth part of which 200 millions is made—in Pennsylvania and West Virginia—into coke, being fully 25 per cent of the country's production of coke. Alabama, Virginia and Colorado make another 15 per cent.

The annual production of coke has quadrupled in the last 25 years and is now about 33 million tons. Nine-tenths of all is yet made in bee hive ovens. Coke is mainly used for smelting iron ore, in a total production for the United States of 23 million tons of pig iron last year.

Around the heads of the Ohio River cluster the grosser manufactures dependent primarily on cheap fuel. Of the 35 million tons of coal mined in the Pittsburg district the one-half is consumed there, a combination of freight tonnage and surplusage unequaled in all the world.

To the responsible individual in this environment, a prominent member of this society has opined the command to be: "Six days shalt thou labor and the seventh make thy repairs": So we learn that thus obedient, we may be promoted above our fellows, and have antics coming to us in a later leisure time.

The coal from the mines of Western Pennsylvania and adjacent is all of the flaming soft coal or bituminous varieties

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* Meeting of Saturday, Dec. 18, 1906.
† 5746 Howe St., Pittsburgh, Pa.

of the market; whether it has come from the *Pittsburg seam*, or from the *Freeport seam* which lies nearly 600 feet lower in the series of rock measures, or from the *Kittanning seam* 175 feet still lower, or from the less broadly prevalent prolific seams occurring between or above and below the three named.

The newer of these seams give a decidedly reddish brown streak in rubbing lumps together, while anthracite is really black. We are reminded that full burned charcoal is really black and burns without smoke or flame but that for some gunpowder making there has been used a less charred wood coal, the more inflammable *charbon rouge*.

Unlike the anthracite beds with their hardest conchoidal fracturing stone coal in those most uptilted, we have the softer coal of the seams at the east, in the more inclined positions; but like the anthracite the percentage of fixed carbon reduces —from 75 to 50—with flatter lay as we come northwest from the mountains across our carboniferous table land. As was the composition affected to lessen the fixed carbon and have increased proportion in volatile matter so was the texture, by the crowding movement from the southeast that had been mountain making farther back east and gradually weakened northwestward.

At the west we have the lumps breaking from the coal vein rather according to the bedding joints, in long flat pieces.

But about Pittsburg we have a preferred raw fuel, the gas coal, in large firm sharp-edged cuboids, as selected lumps after careful mining separating out the well-defined slate bands of the vein.

Then, at the east in the coke region proper, we find the same vein, thicker and softer or tender, easily digged promiscuously to slack or frail lumps of crumbly small cubes, and thus hardly separable as pure coal from the intermingled earthy matter which is scarcely segregated there into plate slates—the coal seam there being vertically fissured through closely and made columnar in grain.

All the differences noted as in geographical sequence agree as consequences of the later side pressure change west-

ward over the whole body of rock strata, originally deposited flat, warping it into basins, etc., with decreasing rate of the dips and the cleavages less near together.

We have here the cleavage direction in parallels ranging 65 degrees to left of the meridian (as the line of smooth faces or 'bord" in the coal veins) across the basins; and the normal, 25 degrees to right of meridian, is the easiest for quarrying or mining out product (called in the mine "on the face of the coal") which direction with the other along the cleavage "on the butt" of the coal makes a rectangular system of development by entries in the coal seam.

But the gradients in such straight mine drifts cannot be regular, for "the strike" or level line in the stratum is affected by the pitch of the basin on the trend of its trough axis (the synclinal), extendedly showing more at the surface by the anticlinical crests between basins being on broken lines and undulating in elevation with a general rise northeastward of 20 feet to the mile; in less complication, but adding to the variations in position, the stratagraphic cross section northwestward shows a profile of reduced waves and declining as to its surface line from the erosions, until the covering glacial drift is met.

In a flat coal mine, besides such rectangular system of face entries (on the face) and butt or cross entries there are apt to be other diagonal drifts perhaps nearer the conforming contours, for drainage or transport favored by gravity, or as long straight avenues graded in refinement from the natural drift elevations.

The charting of the mine workings required every six months to show, on scale not smaller than 200 feet to the inch, the open and closed spaces mined out, needs only to be on the horizontal plan. On these maps the entries are seen to be in pairs, so driven particularly to have the air current making the round by short cut-through every 40 yards. The air's turn may be extended to the face in its progress by carrying forward from the last cut-through a temporary partition, in the entry along the "rib" (pillar) of canvas or boards and called a

"brattice;" the cut-throughs being closed successively by "stoppings" to have only the last one open for the air current thus directed.

The coal seams are found to be thicker in the trough or depressions, and thinner over the next connected hills, than the extensive normal thickness, and the contrast appears within short distances in the "swamps," the small sub-basins only likely found in the practical progress of a mining venture.

Away from here much more frequently than in our Pittsburg field do we find "pinching out" of the vein's top measures uncertainly alternating with upper extra thickening; but we have "clay veins" as dislocations from bottom to top with twisting of the measures centering about the joint filled in with indurated clay, etc.

These are not dignified as "faults" because not markedly affecting the general uniformity of size and position.

The most important, the Pitsburg coal seam, is wonderful in its persistence and the resemblance of its cross section of measures throughout its great width, although gradually changing dimensions. It has the *bands* as two thin slates with a few inches of coal between, about the middle of the height of the section, under the bands it has the *double bottoms*, partially or wholly contributing to product; underneath is fire clay which, as often very hard from contained iron nodules, is erroneously called the bottom limestone; above the bands is the good coal the *breast* and atop is a fire clay about a foot thick about here where it has to be regularly taken down in mining, is called the *draw slate*, and is in some localities all saved for the manufacture of refractories. Above this part of the section that makes the regular open work in the mine, is the *roof coal*, rarely mined for product.

The proper mining out of a seam is a kerfing or *undermining* along the bottom of the face or above in a softer measure of the section, or below in underclay; secondly is the *shearing*, a vertical kerfing at the side, or middle it may be in wide face; both preparatory to blasting with light shots, instead as formerly the taking down by wedge and light pick and as might

be the taking up of bottom with heavy hand pick; all with the purpose of securing lump coal as a specialty.

Blasting from the solid face is reprehensible. Especially so where the heavy shots flaming and in volleys are directly dangerous, and where in hard coal with narrow room pillars these are shattered perforce. The difference in the manner, in the extra labor and less powder of real preparatory mining, is to have a "loose end" or loose bottom or both made by the kerfs extending back 4 to 6 feet with the care to have the two or three shot holes across the face *not deeper*.

Power machines have largely superseded the hand pick for making the undercutting, and with them is the tendency to rob the pillars (even to thinness allowing them to go to waste) in widening the advancing room face instead of leaving the pillars full width intact for complete withdrawal (by some hand work) in the retreat which should be a recovery of all the coal left as support along the advance, but should also in systematic detail of procedure be for a controlled settlement of the roof strata. And further, as entry driving is work paid for on the tonnage basis wholly, or partly only on lineal yardage, the entries are made too wide—more than the 8½ feet width ample for track, etc., and the roof is made unstable, hardly to be corrected by a row of posts objectionable anyhow, and giving space presently to be occupied by dirt under its general definition of matter in the wrong place. Trouble is entailed to add to the coming "squeeze" when in automatic settlement of the overburden in wide room areas left half open, the stresses are shared around to be magnified, and involve even some near solid coal areas in strain prohibiting future mining there; the integrity of the whole upper stratification being widely impaired.

In the interior of our mines as not very deep the temperature is constant at about the average of the year at the surface here 57° F. Small outcrop mines have natural ventilation as upcast at higher openings in the winter and downcast there in the summer, or baffling between, day and night, at the two seasons of the year when the outside temperature is the same about as the inside.

Artificial ventilation generally now compulsory has besome scientific. It is by furnace giving a heated motive air column, or exhaust power fan, to draw out the laden vapors or by blowing power fan to force in air, at one or two inches water gauge pressure difference, and thus having circulating air currents, directed and so "split" inside, between cared for openings outside opposite as intake (downcast) and return (upcast).

Coal mines where explosive gas has been detected are classed as *gaseous* mines and a reading of the Bituminous Mining Laws of Pennsylvania providing for the lives, health, safety and welfare of persons employed therein, is interesting as to this class of mines distinctively.

Natural gas found in the coal seam itself has come from the part extending below water level to exude in the mines palpably at the advance faces on the solid ahead of ventilating excessive air current, or it may come in from higher carbonaceous strata broken into by fall of roof, or be tapped in abandoned gas and oil borings which reach deep, here 2,000 feet below the Pittsburg coal seam, to coarse—but tightly covered—strata, holding as reservoirs those fluid hydrocarbons.

In the mines the gas from fresh broken coal face diffusing into the atmosphere can generally be lighted at its source quietly in the presence of excess of air; and as *firedamp*, the admixture of the gas with air, is as low as 2 per cent detectable by its elongation of the flame in safety lamp held up, in test of the accumulation at the roof. In imperfect ventilation with gas exceeding 20 per cent the lamp goes out. The explosive range is in mixtures of one gas to five air and one gas to fifteen air; the mean of 1 volume of pure gas to 9.6 volumes of pure air is the most explosive.

We have this gas heating our houses, and seek to have that mean of dilution giving a blue flame, from perforations in burner box supplied by gas jet surrounded by air mixer; the distribution in street pipe system being finally at ¼ to ½ pound pressure per square inch, as reduced from high pressure —even of hundreds of pounds—in the main conveying pipe lines.

Natural gas as nearly light carburated hydrogen (CH_4 specific gravity 0.56) has half the gravity of air.

Black damp of the mines is carbonic acid gas, nearly carbon dioxide (CO_2), and has one and one-half times the gravity of air. It is in all the atmosphere of the earth at 3 parts to the 10,000 of air, equal to .03 per cent.

Alex. Silverman (Proceedings of The Engineers' Society of Western Pennsylvania, December, 1903) found the air in Allegheny schools about May 1, 1902, to contain .04 to .20 per cent carbon dioxide. And it is declared (Treatise on Ventilation and Heating, B. F. Sturtevant Co., Boston, Mass.) that assuming the external air to contain .04 per cent dioxide the dilution by the supply of 100 cubic feet of fresh air per minute to each person in enclosed space will keep the vitiation to the tolerable content of .05 per cent of dioxide; there being an accepted production of .6 cubic foot of dioxide per hour by an adult at rest, the calculation for the increment of 1 part in 10,000 is .6 divided by .0001 equal 6,000 cubic feet per hour. It is stated that only 4½ cubic feet of fresh air per minute are required if the 400 parts dioxide in 10,000 parts in spent air of the lungs be immediately removed without contaminating the atmosphere.

Having in mind that the diffusion of gases is inversely rapid as their specific gravities, we see that black damp is less easily removed than firedamp; it lies in low areas of half open abandoned places (where too firedamp may lurk) it is a product of all slow but complete combustion of organic or mineral carbon decay, and animal respiration; and rapid, of fire.

As regards humidity the healthful limit in air of the mines would be 1½ per cent; for a pound of saturated air at 32° F., contains 25 grains of water vapor and at 60° F. 100 grains.

White damp is the name given to carbonic oxide (CO) and as monoxide from the addition of one atom of carbon to the dioxide, its presence signifies imperfect combustion. We get it cold from fresh coal on a grate or hot from a blown out shot in the coal vein. It is of course inflammable, as being ready in its affinity for an increment of oxygen, it reaches for

this with energy when heated. It is the most noxious to the animal economy, not merely suffocating like the rest but a deadly poison on inhalation.

About dust alone being explosive there is difference of opinion; but doubtless it will as it is heated propagate explosion.

On explosion of gas there results nitrogen, steam, and carbonic acid as the suffocating afterdamp mixture, and there is deposit of soot on the cooling with that quick expansion showing for only limited dusty spaces being involved.

The suffix "damp" in firedamp, black damp or choke damp, white damp, and afterdamp is in origin the same as *dampf*, the German word for steam or vapor.

A gas explosion in the mine from accumulation meeting the air and fire, or in the street from a leaking pipe, is a double one; the vacuum created behind induces a quick flow from the source and indraft from the atmosphere for a second weaker detonation than was the prime one which had come after filling a space and pushing to air current.

The mining law requires the circulation of 150 cubic feet of air per man per minute and as much more as will dilute, render harmless, and carry off the noxious gases generated in the mine.

Variations of the barometer indicate changes of the atmosphere's weight constantly; the extremes of pressure differ here during every year by 100 pounds per square foot on all open surfaces. High barometer may mean a penning in of the gases in the strata, and then lowering barometer their quick release at open faces.

Locked safety lamps only are used for mining in the presence of gas, as for making the initial air-ways through the solid to conduct the ventilation in circulation from intake to return air-ways. And these lamps are necessary when the roof is to be broken; as it should be under control for proper settlement in retreat work at the beginning of drawing room pillars, because the subsidence of the roof strata may bring

down some gas; and the lamps are necessary, precautionary, where gobbed old places are to be broken into.

There are mines in which locked safety lamps are exclusively used, by order of the remoter management of the business or periodic inspector, in warding off responsibility, rather than by the competene officer in charge of the work. The Wolf safety lamp, made in Germany, burning naphtha with smokeless light, and openable only in presence of a large magnet, is preferred for such general use.

But the common worker in the coal mines ought not to find gas to hurt him if his place and the whole panel of workings is properly inspected daily and ventilated, and he ought to carry the centre of his sphere of illumination on his cap to guard him up, down, and around, in greater scope of open quantity of light than does the safety lamp lantern. (Fatal accidents inside are now from falls of roof and sides 67%, from gas 9%, from explosives 4%.)

The changes for greater tonnage are with more machinery in every place inside and outside, with men of the Slavonic races, and blasting powder in quantity experimentally flameless, and not yet everywhere resulting in safe economic extraction of the coal seams, but with continued waste of the store in the ground.

Socialism, management by the State of coal mining and transportation is being continually called for, unfortunately; but some of us think that fundamental justice simply applied in taxation of land values, *only*, for the public's benefit that collectively makes these values, should lead off and would in equity do away with the need for invoking the governmental interference between capital and labor. The very existence of a community of men (society), with individual liberty in right relation to it and each other is at stake, some say. Politically we should be wise and happy to see carried out the democratic doctrine of "equal rights to all, special privileges to none," and maintain free discussion with social order.

The fatalities in the bituminous mines of Pennsylvania were last year 444 killed inside and 35 outside; that is one life

was lost out of every 345 employes, or as the comparative statistics for the years have it: 2.90 lives per 1,000 employed, or one life for every 249,000 tons of coal produced. The total for the year was 119,361,514 tons of bituminous coal. This country throughout has had an increasingly bad record as compared with others in accidents in mines, etc. But Pennsylvania last year showed some improvement.

For the year 1905 the list is:

Killed from falls of coal	52
Slate and roof	246
Mine cars	57
Machinery	9
Explosion of gas	29
Explosion of dynamite and powder	7
Explosion of blasts	9
Suffocation by gas	10
Falling into shafts	5
Miscellaneous	20
	444
Outside	35
Total killed	479

Of all, gas accidents are 8%; from falls percentage has increased in 30 years, 40 to 62. Last year's electricity column is vacant.

The marketing of our bituminous coal is generally in the four grades straight or variously mixed together: *The Lump* run over screen of 1¼ inch spaces between parallel bars; the *Nut*, through, then run over ¾ inch straight spaces, or bumped over such less inclined shaking screen, or through holes in revolving screen; the *Slack* that falls through both; and the *Run of Mine* of the three unseparated, but mostly misnamed so hereabout as the first screening is required with stop to weigh the lump for the miner's pay and then one or both the screenings, on their way in the chutes, may be brought in and the grades together loaded into the railroad cars under the tipple:

or the grades can be directly separately loaded according to the demand of the market. Here, screened coal apportions about 66% Lump, 14 Nut, and 20 Slack. The solid coal weighs about 80 pounds per cubic foot.

The comparison of freedom from large and small size impurities of the coal vein, as differences in the grades, depends upon the manner and means of mining. Heavy blasting from the solid face in the mine, that is without preparatory mining, among other results bad generally prevents the selection which is feasible inside (owing to the great regularity of the measures of a vein) with discriminative pick mining or partly machine undermining (all that the power machine can do) and partly hand pick work, as preparatory to lighter blasting and selective loading of the product into the mine cars—unlike this the anthracite is cleaned of slate outside the mine, after the breaking between power rolls; the slate being picked out before and after the various screenings over spaced bars and through square meshed revolving cylinders, to have a numerous series of clean uniform sizes kept separate.

Among the impurities the sulphur seen everywhere as brassy iron pyrites ($Fe\ S_2$) incrusting the "clean coal" is of less import there than it is generally in the "binder" slates it makes heavy. There occur sulphates of lime and of alumina as curiosities. Organic sulphur, as compounded with carbon and hydrogen, is not in evidence except by analysis adding to the percentage of sulphur, nor does it clinker the ashes separating as the waste in fires. Sulphur as a fuel has about one-fourth the value of carbon.

In the present coke regions separation of the earthy matter, the slates, is scarcely required and what is wanted in the ovens is the smallest lumps to favor the charring to homogeneous coke; the vein readily yields a friable product to pick or powder.

In the coke region in contradistinction to the gas coal region, the working of mine rooms is narrow (of 4 yards width with one row of props, against the 7 to 10 yards in the hard coal) and the retreat is of wide room pillars (even exceeding

20 yards) taken, drawn out, totally obtained as product—together with the "heading" (entry) pillars from the inner end of a section of the mine in diagonal line running between face and butt in range of the faces working, for systematic exhaustion and closing in, with purposed subsidence of the roof and relief therefore from "squeeze" as extended pressure hanging over, or "creep" as raising of the entry footing and tracks from displaced soft clay forced into the open from under the weighted pillars alongside, by live roof.

The burning of bituminous coal we all understand is not necessarily a smoke nuisance. At replenishing of the fire the heavy hydrocarbons dislodged at the start give out brown tarry vapors and then as they split up, water vapor and burnt gas; but with the great absorption of the heat this vapor is in the vesicular form of steam and blackened by particles of condensed carbon; and the cloud of smoke coming only for a minute and it may be only once in fifteen, unfurls to stain the environs. After our Prof. Trinks the case may be stated thus: Ample supply of preheated air above the fire of the boiler furnace to burn the carbon as well as the hydrogen at the time of stoking, is the preventive. That supply automatically issuing from pipes placed for the purpose, at the proper time, prevents also the non-conducting soot deposit on the shell, and there is a raising of heat effect from 72 per cent to 82 as the fuel's total yield to the boiler. The theoretically perfect even dosing of sized coal upon the shaking grate of the mechanical stoker may, at a vacancy letting extra cooling air leak through and preventing combination of all the carbon with oxygen, in defective working, show small but steady smoking at the stack's top in amount aggregating to that of the other intermitted but imposing smoke cloud so very patent. The waste gases allowed to escape by forced or chimney draft should carry 13 per cent carbonic acid and be at 290° F., the temperature of the steam boiler.

Of especial local interest it is that we have here above the river level, the geologic horizon of the Crinodial Limestone, midway between the Pittsburg coal above and the Freeport

coal below, marking by the fossil remains the ending of the marine old life and the beginning of the fresh water deposits and organisms. Another change in the plant remains is seen when the rocks 700 feet higher are reached atop the Waynesburg coal seam—of which, however, only a remnant is left in Allegheny County, in Bethel Township—where we first meet in going upward in the series of these sedimentary groups of limestone, fireclay, coal, shale, and sandstone, a modern flora —higher than the Ferns of which 600 species had become extinct in these Paleazoic formations below which are so defined at their top, and from which their extent of thickness is a mile or two down vertically through Carboniferous, Devonian, and Silurian formation strata.

We are here at the surface as our ground, on the eroded terraces of the Lower Barren division and of the Upper Productive, of the Carboniferous formation.

We believe now that the old ranker vegetation had little directly to do with giving us the store of fossil fuel, the coal beds; but that like the formation of the peat bogs continuing in our day, lowly mosses an inch or two high in quiet growth at the spot, made these coal measures of even thickness so marvelously extensive.

DISCUSSION.

Mr. Thos. H. Johnson, Member: I was listening for one point in the paper that I did not hear. I would like to have Mr. Schellenberg tell us something of the relation between mine explosions and low barometer.

Mr. Schellenberg: Well, I once wrote an article on that subject. The gist of it is that while with low barometer we have a dangerous condition, yet it is like the weather changes as connected with the barometer, it is the change of pressure. It is at the time of high barometer that we have to anticipate the danger of low barometer, but it is the falling of the barometer that makes the difference. The total change here is 100 pounds per square foot, from 28.3 to 29.7 inches of mer-

cury; and changes come very quickly sometimes. And we have to look out for more gas exuding, after a high barometer, at the time of its lowering.

Mr. Johnson: Mr. Schellenberg has not yet quite covered the point he brought out to me in conversation, that as a matter of fact all of the notable mine explosions in this country have occurred in periods of low barometer following a rapid fall of the barometer.

Mr. Schellenberg: Well, I have referred to the fact that it occurred. But gas explosions in street mains when we used illuminating gas always occurred in the winter when the surface of the ground was frozen and the leaking gas could not get out easily, and so collected. The Harwick mine explosion, you understand, occurred because of the freezing up of the air ways. Where the air was to go from the fan into the mine the low places were allowed to be clogged up at the bottom with ice so that less air got in the bottom. There is nothing mysterious in that.

Mr. Loeb, Non-Member: I would like to hear Mr. Schellenberg's explanation of the bands in the Pittsburg coal.

Mr. Schellenberg: If I knew that I would know everything. It is like the "flower in the crannied wall." But that, to me, is convincing that the coal bed cannot be a drift formation. It extends for a hundred miles width here and it extends to the south a greater distance. We know the Pittsburg coal by those bands, and they maintain their relative position.

Mr. E. Yardley, Member: How thick are those bands?

Mr. Schellenberg: Six or eight inches, with the little coal between two one-half inch to one-inch slates.

Mr. Yardley: Have you no theory or supposition in your own mind as to how they were formed?

Mr. Schellenberg: Well, those measures were all horizontally formed in bogs, but why they should have had those bands, or sometimes others of slate or earthy matter, I don't know.

MR. YARDLEY: Wouldn't it be made if some bog was overflowed with muddy water?

MR. SCHELLENBERG: Yes, and so there are other slate binders part of the time, not continuous, but they come in and go out. And then sulphur will occur in an irregular manner, too. We do not know very much about the sulphur either.

MR. C. L. LIVINGSTONE, Member: Do those veins, the Pittsburg, Freeport and Kittanning, maintain a practically uniform level?

MR. SCHELLENBERG: Relatively. I place the Pittsburg nearly 600 feet above the Freeport. As we go farther west the interval decreases and the measures decrease, too. The intervals and measures are very apt to decrease together.

MR. LIVINGSTONE: But not absolutely level above the Freeport?

MR. SCHELLENBERG: No. I have told that they change in waves as you come across from the mountains. The Pittsburg changes from here in our latitude we will say from about 430 feet to 1,300 feet above sea level up here on the Perrysville road: north in Westmoreland county it gets up to 1,300 feet and east of the Chestnut Ridge it is thrown up higher than that. Then I tried to describe the basin troughs running from southwest to northeast, the whole of the rock deposits rising to the northeast at the rate of twenty feet to the mile. Oil is found in sands in Venango county 800 feet deep and in the same sands in Greene county 3,000 feet deep. That shows the change to the northeast as in those entries there on the map north 25 east 20 feet to the mile, but undulating, that is, every time the whole body goes up it goes up more than it went down south of that.

From these mine maps we have the key to the changes that occurred. We believe first the strata were laid down flat, then were crumpled and the streams went to the lakes; they were tributary to the St. Lawrence as it extended back up them. They came through those ranges in a northwesterly direction and the Beaver river ran the reverse way. The bed

rock there shows that it ran the other way, and so did the Muskingum and all the rest of them. Then came the great ice. That brought in a lot of drift and covered the whole thing over and turned those streams around so that the Ohio river that was going northwest up the Beaver Valley had to turn around and go south. The streams all run northwest and northeast, just as rectangular as that underground work on the map. They can't help it. Here the Allegheny has endeavored to come in at right angles to the Monongahela.

MR. YARDLEY: Does the Pittsburg vein extend east of Chestnut Ridge?

MR. SCHELLENBERG: The Pittsburg vein runs out in those hills. However, Mr. McGrew's mine map here on the wall shows a part of a considerable fragment north of Ligonier in Westmoreland County. The main body extends to Charleston, W. Va. Southeast there is, or rather was, a field of it on the Potomac, the big Cumberland coal vein now pretty nearly exhausted, was Pittsburg coal. In Pennsylvania the farthest east region is in Somerset county, about Salisbury.

MR. YARDLEY: How far does it extend south?

MR. SCHELLENBERG: It extends into Ohio through Jefferson and Belmont and adjoining counties. Farther down they do not seem to know whether they have it continuously or not.

H. C. BABBITT, Member: Are there two Freeport veins?

MR. SCHELLENBERG: Sometimes there seem to be, and then again there is only one. Over in Ohio the Freeport, extensively mined, is called No. 6 (but latterly some of this mining is designated as being in No. 7), and the Pittsburg is No. 8. In eastern bituminous region the Lower Productive series has the Freeport upper vein designated "E," the persistent Kittanning lower being "B;" and there "D" or "Lower Freeport" is extensively mined and preferred for quality to "E."

MR. M. KNOWLES, Member: The gentleman spoke of two systems of mining. I would like to ask whether there is a difference in settlement, after some years, according to which

system be used, viz.—first where the piers are left in, and secondly, where the whole of the coal is taken out.

MR. SCHELLENBERG: The right way to mine coal is to take out the entire coal and settle the surface. This thing of pretending to keep up the surface by leaving pillars means their loss unless in this neighborhood you take no more than half the coal.

MR. KNOWLES: And will the settlement be approximately the thickness taken out?

MR. SCHELLENBERG: Of course at outcrops you see the whole sinking of it, but as you go under farther and deeper the sinking becomes mere fissuring at the surface because it only loosens up the stratification and of course less and less disturbance appears at the surface. There is another advantage of taking out all the coal in the gaseous mines and that is that breaking to the surface lets out the gas.

MR. KNOWLES: After all the coal is taken out do I understand the surface will not settle anything like the thickness of the vein that has been removed?

MR. S. A. TAYLOR, Member: I might answer the question of Mr. Knowles that it depends entirely on the thickness and nature of the covering over the coal. As the mining approaches the surface, where the covering over the coal is shallow, and all the coal is exhausted, you will get a sinking of the overlying strata approximately the depth of the vein, but as you come to the higher elevation and thicker cover, you will not get so much showing as to actual difference in elevation of the surface.

While I am on my feet there are a few things that came up in the paper that I believe might be touched on with some advantage. As to the position and location of the synclinal and anticlinal axis forming the troughs which Mr. Schellenberg referred to, these occur in lines practically parallel to the main direction of the Appalachian chain of mountains, changing as you go south to a more northeasterly and southwesterly direction.

Another thing referred to in connection with the Pittsburg coal was the matter of bands, commonly called by the miners the bearing-in bands. The occurrence of these bands were so prevalent in the Pittsburg seam that for many years it was understood that that was one of the ways to determine the Pittsburg coal. Until a few years ago I had never seen the Pittsburg seam where these bands did not occur, but about two years ago I was called into a case with Prof. Brown of the University of West Virginia, in connection with some coal south of Weston, W. Va., to determine whether it was the Pittsburg seam or not. In this locality the measures have taken on an entirely different form. They are magnified greatly, and these bearing-in bands do not exist in that section. Neither does the fire clay separating the roof coal from the breast coal, known as the draw slate, occur at this place, and it was only after some considerable investigation that we were able to determine that it was Pittsburg coal by discovering the crinoidal limestone which occurs some distance below the horizon of the Pittsburg seam.

Another point mentioned by Mr. Schellenberg in connection with the number of accidents caused by the falling of coal and roof. I believe there is an explanation of these figures found in the method of mining. In the methods of mining carried out before the advent of mine machinery, the work was all done by hand pick mining, the coal being undercut between the bands above referred to. After this was done the coal was cut up the one side by shearing along the rib by a miner, before he began knocking the coal. The coal was then knocked by the use of a wedge and sledge instead of powder. Today we have abandoned that method of procedure and in lieu of it the coal is now undercut near the bottom of the seam, either with a puncher or electric machine, and there is no shearing done along the rib side, but instead thereof there are holes drilled near the rib on each side of the working place, and a heavy charge of powder or other blasting material is fired. These heavy charges of powder being exploded, fre-

quently shatter the ribs, as well as the roof, with the result that the roof is weakened to such an extent that the place required to be cleared of posts in order that the mining machine may work satisfactorily, is such that the roof will drop between the posts, and this with the inexperienced men who find employment in the mines to-day, accounts largely for the number of accidents. I might add also that another result of this heavy shooting is that the ribs between the main working places are so weakened that although drawn by hand mining, it is impossible to recover as much coal as was formerly recovered in the withdrawing of these pillars.

Another matter mentioned by Mr. Schellenberg was in connection with the ventilation of mines before the time of furnaces and other artificial ventilation, brings to my mind a little experience which I had some two or three years ago in connection with the ventilation of a mine, which might be interesting to relate. There was a drift mine situated in the tops of the hills, which outcropped on three sides. In the early morning when the sun was shining on the eastern outcrop, the air current was in that direction. In the afternoon when the sun had passed to the west and was shining on the western outcrop, the air in the mine passed westwardly. The solution was mentioned by Mr. Schellenberg, namely, the difference in the temperature between the outside air and that of the mine. The outside air being much higher in temperature causing the cool air of the mine to pass in the direction of the location of the sun, and only emphasizes what natural causes will do towards the ventilation of a mine.

As to the matter of dust explosions mentioned in the paper, I believe that the best way to understand this matter is to observe the ignition of coal dust as it takes place in a malleable iron furnace, the coal having been first ground down into a fine powder, is injected into the furnace by a jet of air. After the furnace has become hot the combustion takes place almost instantly upon the fuel's arrival in the furnace.

In speaking with Mr. Schellenberg about this paper a few days ago, I mentioned to him some facts in connection with the use of coal of the Pittsburgh district, which it had been my privilege to investigate, and he asked me to mention some of these figures in connection with his paper. Just following that the citizens of Pittsburgh had brought to their attention a request by the Rivers and Harbors Committee of Congress to pay for the rebuilding of Lock No. 5 of the Monongahela River, and while the citizens of Pittsburgh refused to contribute to this expense, I believe if any person outside of the National Government should contribute to it, it should be the large corporations which are receiving their supply of fuel from this source, as the cost of their fueling is reduced to them by the saving in freight, and does not redound to the general advantage of the public at large. The figures which I wish to give, are largely taken from the reports published by the U. S. Geological Survey, and I believe will be of interest in this connection.

The total output of coal produced in the United States from 1814 to the end of 1905 was 5,970,773,571 tons. Of this amount Pennsylvania produced 3,331,256,468 tons, or 1,774,-623,598 tons of anthracite and 1,556,632,870 tons of bituminous coal, or practically 57% of the entire output of the United States for the past ninety years.

The output of coal in the world in 1905 was 1,033,125,971 tons,
The output of coal in the U. S. for 1905 was 392,919,341 tons, or 38% of entire output of the world.

The output of Pennsylvania in 1905 was 196,073,487 tons, or almost 50% of the entire output of the United States.

Of the output of Pennsylvania, 19.8%, or practically 2/5, was anthracite.

Of the output of Pennsylvania, 30.2%, or practically 3/5, was bituminous.

The production of bituminous coal in 1905 in Pennsylvania was 118,413,637 tons.

This amount was	118.5	times what was mined in 1850
This amount was about	44	times what was mined in 1860
This amount was over	15	times what was mined in 1870
This amount was over	6	times what was mined in 1880
This amount was over	3	times what was mined in 1890
This amount was over	1½	times what was mined in 1900

and the increase in 1905 over 1904 was 20,475,350 tons, an amount 20½ times the output in 1850, practically 10 times the output in 1860, 3 times the output in 1870, and more than was produced in 1880 by practically 2,000,000 tons.

While the average sale price of bituminous coal in 1880 was $1.367, in 1905 it had fallen to $1.062, or a loss of 30.5c per ton; while all materials entering into the production of coal are now increasing at a much greater percentage.

The exact average sales price of coal from the Pittsburgh district for 1905, I do not have at hand, but I am satisfied from figures in my possession, and by analysis of reports of various companies that it would not exceed 95c per ton f. o. b. cars mines, and this price did not allow a net profit of much over 5c per ton to one large company in this district. This is a grave question and one worthy of serious consideration, when we note with what rapidity we are exhausting our resources, without any fair or adequate compensation therefor.

SHIPMENTS OF COAL TO AND THROUGH PITTSBURGH DURING THE FOLLOWING YEARS:

Year.	Total Shipments.	Approximate Local Consumption.
1901	23,001,126 tons	9,430,000 tons, or about 41%
1902	28,898,931 tons	12,950,000 tons, or about 45%
1903	30,172,614 tons	15,500,000 tons, or about 51%
1904	27,840,787 tons	12,500,000 tons, or about 45%
1905	33,318,240 tons	17,500,000 tons, or about 54%

Year	Passed through locks on Mon. River.	Passed Davis Island Dam, Ohio River, near Pittsburg. (From annual reports, Ohio River Improvement).	Difference, approximate consumption of river coal at Pgh.
1890	4,652,104	3,420,357	1,231,747, or 27%
1891	4,276,588	2,893,752	1,382,836, or 32%
1892	3,872,340	2,299,294	1,573,046, or 40%
1893	3,860,072	2,364,401	1,495,671, or 31%
1894	4,649,612	2,453,787	2,195,824, or 47%
1895	4,183,596	2,393,596	1,789,723, or 43 %
1896	5,709,252	4,102,190	1,607,062, or 28%
1897	5,289,838	2,670,369	2,619,469, or 50%
1898	6,120,800	2,979,494	3,141,306, or 52%
1899	5,569,967	2,709,140	2,860,827, or 51%
1900	5,817,863	2,557,470	3,260,393, or 54%
1901	7,945,480	3,283,353	4,662,137, or 59%
1902	9,305,927	3,619,905	5,686,022, or 61%
1903	9,372,664	3,069,299	6,303,365, or 66%
1904	6,985,576	2,811,584	4,173,992, or 60%
1905	9,484,860	3,926,319	5,558,541, or 59%

1903 was the year of the anthracite strike and those figures can be explained in this way, that the railroads could reach the markets where higher prices were demanded while the river could not, consequently the railroad coal was shipped out and the river coal was consumed at home.

I have not attempted to make any figures on how long this could be continued, but it ought to bring to our minds one thing, that we are very rapidly exhausting our treasures in Pennsylvania, and specially in the Pittsburgh district, and not getting the fair compensation for this coal it deserves.

The coal is sold to large consumers here at a price which does not give to the owner or operator of the mines what he should receive, or what any other kind of mining does receive, and therefore the general enrichment of the district from this

source does not accrue, except in the enlargement of profits by the consumers who use so much of it. The rapidity with which we are exhausting the coal which is tributary to the Monongahela River, and consequently carries with it the low cost of transportation, is one which is a matter of serious speculation, when we consider the potent factor it is in the manufacturing supremacy of Pitsburgh.

Mr. Flanagan: When Mr. Schellenberg referred to the greater freedom with which gas is liberated during a falling barometer it occurred to me that there is a rather homely illustration which would make it evident that it does not require very much change to produce such results. Many people have noticed that when they turn the gas on in the house they get a better flow on the upper floor than on the lower floor. It is very marked in a three-story building. There is a popular superstition, very much encouraged by newspaper scientists, that this is due to the fact that the gas is so light that it exerts the greatest pressure in the upper pipes; that it reverses the action of gravity and presses with greater force at the top. It is not likely that the people assembled in the room here will accept such a theory. The lightest gas has some weight and really has a slightly greater pressure in the lower rooms. The real reason that the gas issues from the jets in the upper rooms with an apparently greater pressure is that it meets with less resistance. The slight amount that the atmospheric pressure is reduced by reason of the greater elevation will probably account for the gas coming out with a seemingly greater force, although the pressure within the pipe is actually some small trifle less, and will illustrate the point that a very slight falling of pressure registered by the barometer permits a much greater freedom in the flow of gas from the coal surface, or from the pockets in which it was heretofore held.

Mr. A. E. Duckham, Member: I believe Mr. Schellenberg said that about 10% of the total accidents are due to mine gas and about 65% to falls of slate. Is it not peculiar that in the newspapers you see so much about the danger and acci-

dents from fire damp, and very little about the fall of slate? And is it not also possible to prevent these accidents? We are very particular to have mines inspected for fire damp, but is there not a good deal of carelessness among mine operators in reference to falls of slate?

MR. SCHELLENBERG: Mr. Taylor attributed it to the general use of powder firing. He answered that.

[Acknowledgment for the mine maps here displayed is due Mr. E. W. Fohl for map of Chalfant Mine, *Allegheny Co.;* to Mr. Edward McGrew for map of Orient Mine, *Fayette Co.*, and Colonial Mine, *Westmoreland Co.*]

ERRATA.

Substitute the following table for the one on page 380, November 1906 Proceedings:

Gas	a	Value of V when C =	
		1,000 grams 1°C Per Sq. Ft. per min.	Therms Per Sq. c. m. Per sec.
Atmospheric air	.45	.001926	2.239×10^{-6}
Hydrogen	.38	.010571	12.289×10^{-6}
Carbonic Acid	.517	.001196	1.391×10^{-6}
Olefiant Gas	.501	.001841	2.139×10^{-6}

Abstract of Minutes

ENGINEERS' SOCIETY
OF
WESTERN PENNSYLVANIA

FEBRUARY 1906—JANUARY 1907

PITTSBURGH, PA.:

PUBLISHED BY THE SOCIETY,
803 Fulton Building,
Sixth Street and Duquesne Way.

1906

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

Vol. XXII FEBRUARY, 1906 No. 1

ANNUAL MEETING.

The 26th Annual Meeting of the Engineers' Society of Western Pennsylvania was held at 410 Penn Avenue, January 5th, 1906, at 8:20 P. M. President Samuel Diescher in the chair and 50 members present.

The minutes of the 25th Annual Meeting were read by the Secretary and approved. The report of the Board of Direction was read by the Secretary, recommending that 59 members be dropped from the rolls for non-payment of dues.

On motion the recommendation of the Board was adopted and they were dropped from the rolls.

The Secretary then read the report of the Board and of the Committees.

REPORT OF THE BOARD OF DIRECTION.

The Board has held 10 regular and 7 special meetings. Average attendance of members of the Board 5, average attendance of members and ex-officio members 8.

Business transacted includes payment of bills by voucher.

Stopped publishing Proceedings in August and September.

Instituted a Finance Committee.

Instituted a Publication Committee.

Improved Proceedings by issuing promptly, by better paper, regular makeup and by printing new members names only after they have become members.

Reduced subscription price of Proceedings to schools and libraries to $1.00 per year.

Rented a Safe Deposit Box.

Invested $7,200.00.

REPORT OF RECEPTION COMMITTEE.

The President and Board of Direction,
Engineer's Society of Western Pennsylvania.
Pittsburgh, Pa.

Gentlemen:

Your Reception committee for the year 1905 reports that the custom of the preceding year as to Informal Dinners, preceding the regular monthly meetings, was continued from January to May. The number participating on these occasions was very small. The committee consequently felt that this feature was not desired by the members and stopped the practice.

Smokers were held at Hotel Schenley, April 29th, and December 9th. These were thoroughly enjoyed by all taking part and stimulated the best of good fellowship which, we would say, is eminently essential to the successful engineer.

Excursions of inspection to keep in touch with progressive Pittsburgh resulted from the efforts of the committee. These occurred as follows:

Pressed Steel Car Company's Plant, McKees Rocks, February 25th.

United States Glass Co.'s Plant, South Side, Pittsburgh, March 10th.

United States Weather Bureau, Pittsburgh, March 18th.

Duquesne Steel Works and Blast Furnaces, Duquesne, April 7th.

American Bridge Company's Plant, Ambridge, Pa., May 27th.

Blowing Engines installed by Mackintosh-Hemphill & Co. at the Carnegie Furnaces at South Sharon, Pa., also the mills of the American Wire Company at same place, October 28th.

Filtration Plant for City of Pittsburgh, Aspinwall, Nov. 18th.

Attention is called to the large attendance at these excursions. On no trip was there less than one hundred and twenty-five, the maximum number being three hundred and fifty. As the average attendance at the monthly meetings of the Society was small in comparison, your committee feels that this feature of their work met with the heartiest approval of the members. The guests were handsomely entertained on these occasions, due credit having been given already in the monthly reports. The trips were full of profit and pleasure.

The Society will probably be located in better and more favorable quarters during the first half of the new year. Conditions will be more favorable for the social side of the organization. We hope this will develope more and more as the years roll by.

The Annual Banquet is scheduled for January 26th, 1906, at Hotel Schenley. This event will finish our work and we hope to have the same meet with your approval.

Respectfully submitted,

George T. Barnsley,

Chairman Reception Committee.

REPORT OF PROGRAMME COMMITTEE.

The President and Board of Direction,
Engineers' Society of Western Pennsylvania.
Pittsburgh, Pa.

Gentlemen:

Your Program committee submit the following report. At each of the ten monthly meetings of the Society original and comprehensive papers were read and discussed, the respective subjects having been as follows:

Flow of Water through Pipes Fed by Reservoirs.
Reconnaissance for Platinum Metals in British Columbia.
Wooden Stave Pipe.
Factors that Affect Results in Painting.
Compound Reversing Engines.
Outlines of Mine Ventilation.
Electric Motors and their Application.
Centrifugal Fans.
Producer Gas and Gas Producers.
Heat Insulation.

Some of these papers disclosed original research by specialists in their respective lines, others dealt with the subjects in a more general way giving what has been accomplished up to date and one or two more papers had the character of illustrated lectures.

We have also provided for a paper in January and if necessary for February and we would suggest that this practice be continued in the future, as the incoming committee cannot be expected to arrange for papers any sooner.

Our first aim always was to treat important and live subjects and to solicit contributions from members of the Society whenever possible. We also succeeded in getting several valuable papers from outside authorities, and in only one case was it necessary for us to ask the Society for a small outlay in this direction.

The plan of having one paper read on each subject and bringing out the different opinions in the discussions worked

very well and in our opinion is superior to the plan of having many small papers on the same subject, as they often overlap and consume too much time.

For the future we beg to submit the following suggestions: The title of an author, especially if he is a non-member, should be given with the paper. This will add considerably to its value and is a courtesy to the writer. It is also one of the best means to interest the members and to induce them to come to the meetings.

For the same reason we suggest that in the future a short synopsis of the paper be given in the announcement.

We further suggest that the program committee be made responsible for every paper and its contents appearing in the Proceedings (the Sections not excepted) subject to approval of the Board of Direction, all as provided for in Article IV, Section 8 of our By-Laws. We do not consider it wise that the Secretary should rule in these matters,

Respectfully submitted,

A. Stucki,

Chairman Program Committee.

REPORT OF HOUSE COMMITTEE.

The President and Board of Direction,
Engineers' Society of Western Pennsylvania.
Pittsburgh, Pa.

Gentlemen:

Your House committee appointed for the year 1905 report as follows:

In view of the fact that the lease which we hold on our present building is to expire April 1st, 1906, the work of the House committee has been carried along on somewhat different lines. It has been our endeavor to keep the rooms clean and pleasant, but we have neglected doing considerable work in order to spare the expense and make it possible after we

are located in new quarters to expend the money in improvements at that time.

The expense connected with the repairs to the building have been slight, considering the bad condition of the same. Our furniture is in need of refinishing, or polishing, our draperies and curtains are about ready to be discarded, and the carpets are in quite poor condition.

We feel that this explanation may be of some interest to you in view of the fact that your committee has always aimed to keep the premises in the very best condition, and were it not for the fact that we are about to re-locate, we would have had all this work done.

We present a statement showing the net cost of our quarters:

Gross cost present quarters		$ 1,920 12
Rent from Foundrymen's Asso.	$ 80 00	
Rent from Willcox & Gibbs	798 00	
Sale of chair of former tenant	15 00	
		893 00
Net cost of house		$ 1,027 12

Respectfully submitted,

Fred C. Schatz,

Chairman House Committee.

REPORT OF LIBRARY COMMITTEE.

The President and Board of Direction,

Engineers' Society of Western Pennsylvania.

Pittsburgh, Pa.

Gentlemen:

Your committee report that for want of suitable quarters they have been unable to put the library in shape for access and use. We hope, however, that when the Society moves into new quarters on April 1st next our successors will find

ample room to place the Library in proper shape, so that the valuable collection of books may be accessible.

No binding had been done since 1898, and the number of unbound periodicals had since been accumulating, many of which are too valuable to sacrifice. This accumulation we have overhauled, sorting out those which were of greatest value and having them bound. Others of less value were sold as waste paper.

The number of volumes bound was 216—as per the following list:

Engineering	14	volumes
Engineering & Mining Journal	14	"
Electrical World	7	"
Railroad Gazette	6	"
Engineering News	11	"
" Record	14	"
" Magazine	14	"
Journal Soc. Chemical Industry	8	"
Municipal Engineering	22	"
American Chemical Journal	13	"
Fielden's Magazine	4	"
Trans. Am. Institute Elect. Engrs	1	"
Engineers' Club, Philadelphia	8	"
Journal Association Eng. Society	13	"
Journal Franklin Institute	14	"
Proceedings Western Railways Club	12	"
" Acad. Nat. Science, Phila	11	"
Journal Western Society Engineers	7	"
" Society of Arts	7	"
Trans. Am. Soc. Mech. Engineers	8	"
Trans. Am. Inst. Mining Engineers	8	"
Total	216	

We have expended

For missing numbers	$ 9 26
" labor sorting periodicals	13 70
" express	4 20
" Binding	186 60
" Printing	4 00
	217 76
Received for waste paper sold	37 93
Net expenses	$179 77

During the past year all the periodicals received at the rooms of the Society have been by exchange, with the exception of two, and as these two were not sought for and consulted by the members they have been stopped. The periodicals for the coming year will, therefore, all be exchanged and require no outlay for subscription.

There has been no complete catalog of the library for a number of years past, and under present conditions it is not practicable to make a list of the books we have. When we move into new quarters where the books can be properly arranged, a complete list should be made and printed for distribution to the members.

Respectfully submitted,

Thos. H. Johnson,

Chairman Library Committee.

REPORT OF PUBLICATION COMMITTEE.

The President and Board of Direction,
Engineers' Society of Western Pennsylvania.
Pittsburgh, Pa.

Gentlemen:

The Publication committee submit herewith their report for the fiscal year ending December 31, 1905:

The committee (then known as the Advertising committee), was appointed for the purpose of investigating the general subject of advertising and particularly the existing contract. After investigation by the committee and upon report to the Board, it was decided that the old contract had been so indefinitely carried out that it would be wise to have a new one. Accordingly there was an agreement entered into with Mr. F. A. Ensign by the committee acting in behalf of the Society, as authorized by the Board of Direction, which agreement provides, briefly, that Mr. Ensign shall continue the advertising still in force to the expiration of the several contracts, none of which were to exceed 12 months; he to collect all money for the same and turn over to the Society 50% of the proceeds. Upon the execution of this agreement and as part of the program approved by the Board of Direction in which it enlarged the powers of the Committee, and designated hereafter to be known as the Publication committee, there was a notice published in the July issue of the Proceedings that hereafter the Society would conduct its own publication and look after its own advertising. Subsequently, with the approval of the Board, an advertising solicitor was employed, his services commencing upon September 18th, 1905.

Since the solicitor took up his work, contracts have been

made for 43 advertisements, the total amounting to $992.60. The details are as follows:

1	contract	at	$ 4 60	$ 4 60
12	"	"	10 00	120 00
20	"	"	21 00	420 00
5	"	"	36 00	180 00
2	"	"	37 00	74 00
1	"	"	50 00	50 00
1	"	"	60 00	60 00
1	"	"	84 00	84 00
	Total			$992 60

Of the above listed amounts, $127.00 was secured by the Secretary, leaving $865.60 as the amount against which the expenses of the solicitor should be charged, viz; $257.50 plus commission $108.21, making a total of $365.71, or 42%.

The committee feel that there has been undertaken a responsible experiment and possibly advertising will cost a greater percentage than heretofore through an advertising agency, but the committee believe it has interpreted the wishes of the Society correctly in the desire to have the Society conduct its own publication and handle all the business. It will certainly cause the Board and thus the Society through its representatives to be kept in closer touch from time to time with this work.

There has been received from Mr. Ensign the following payments from the three publications issued since the new agreement went into effect:

October	$130 54
November	In dispute
December	$126 25

The above amounts are correct and agree with the list given by Mr. Ensign in the agreement dated July 27th, except for certain contracts which have been cancelled. The November account is in dispute because nine advertisements did not

have copy changed as desired, although our solicitor states he gave opportunity for this.

After the cancellation of the contract with Mr. Ensign, which included the printing of the Proceedings, it became necessary for the Society to make new arrangements for this publication. Upon receiving itemized bids from six carefully considered and large establishments, it was found that the former cost would be exceeded and upon careful analysis of the situation and after refusal of the former printer to continue work at the old rates, the commitee learned that a newly established house would consent to publish the periodical at practically the old rate, i. e.—at the blanket price of $1.50 per page for 1000 copies and $4.00 for each additional 100 which, under the circumstances, was considered better than to make an agreement upon detailed itemized prices. This upon being reported by the committee and approved by the Board of Direction, a contract was entered into with Percy F. Smith, dated October 16th, 1905.

The summary of the costs and revenue for the three months during which the Society has had entire control of the Proceedings is as given below:

Cost of Proceedings for the Months of October, November and December, 1905.

Printing	$492 27	
Cuts	31 44	
Postage	42 85	
Envelopes	7 05	
Express	3 45	
Total		$577 06
Cost of advertising:		
Solicitor's salary	$257 50	
Solicitor's commission	108 21	
Legal and auditing	45 00	
Printing	7 00	
Postage and Miscellaneous	11 45	
Total		$429 16
Total expenses		$1,006 22

Revenue.

Received from F. A. Ensign 50% of advertising, according to old contracts.

October....	$130 54	
November..	117 92 (estimated amount) but subject to revision	
December..	126 25	
		$374 71
Estimated first quarter receipts on new advertising		244 00
Total		$618 71

This shows that 62% of the cost of publishing the Proceedings is paid for by the advertising.

Respectfully submitted,

Morris Knowles,

Chairman Publication Committee.

REPORT OF FINANCE COMMITTEE.

The President and Board of Direction,
Engineers' Society of Western Pennsylvania.
Pittsburgh, Pa.

Gentlemen:

Your Finance committee report a system of accounting has been established. We believe the benefit will be made apparent in the next few years, as this will produce information in such a form, that it can be analyzed by the Board. The committee has given attention to the auditing of receipts and disbursements quarterly; for the reason that it affords a more complete and detailed examination than would be possible if delayed to the end of the fiscal year.

A good percentage of the Society's surplus funds were invested in bonds during the year. The accounts of the Secretary and Treasurer have been examined and found to be correct and in accordance with the statement which will be furnished at the Annual Meeting.

Respectfully submitted,
J. K. Lyons,
Chairman Finance Committee.

REPORT OF NEW BY-LAWS COMMITTEE

The President and Board of Direction,
Engineers' Society of Western Pennsylvania.
Pittsburgh, Pa.

Gentlemen:

In behalf of the committee appointed to revise the Charter and By-Laws we make the following report:

The committee has revised the Charter and the same is now before you for consideration. It has held several meetings to revise the By-Laws and it is hoped to complete the work at the next meeting which is to be held in two or three weeks.

Respectfully submitted,
Willis Whited,
Chairman New By-Laws Committee.

REPORT OF COMMITTEE ON TIMBER TESTS.

The President and Board of Direction,
Engineers' Society of Western Pennsylvania.
Pittsburgh, Pa.

Gentlemen:

The committee on Timber Tests report that it is assembling specifications and data of all kinds pertaining to the commercial uses of timber, and will during the winter months

reduce same to some form of general specification, after which it is the express desire of a number of the members to turn this data and the results of our findings over to the American Society for Testing Materials, believing that they are better equipped for this work and will give the subject a wider circulation than is possible for us to bring about.

Respectfully submitted,

E. K. Morse,

Chairman Committee on Timber Tests.

ANNUAL REPORT OF TREASURER.

The Treasurer begs to present the following exhibit of the finances of the Society for the year ending January 1st, 1906, as shown by his books at that date:

Cash receipts from all sources	$10,406 99
Operating expenses	8,761 63
Excess of receipts over expenses	$ 1,645 36

Receipts in detail:

Dues, Resident 1902	(4)	$ 28 00		
" Non-Resident 1902	(1)	5 00		
			$	33 00
" Resident 1903	(21)	168 00		
" Non-Resident 1903	(9)	45 00		
" Account 1903	(4)	14 25		
				227 25
" Resident 1904	(89)	712 00		
" Non-Resident 1904	(28)	140 00		
" Account 1904	(6)	15 25		
				867 25

" Resident 1905	(563)	4,504 00	
" Non-Resident 1905	(185)	925 00	
" Account 1905	(74)	280 56	
			5,709 56
" Resident 1906	(3)	24 00	
" Non-Resident 1906	(1)	5 00	
" Account 1906	(5)	13 11	
			42 11
Life Membership	(1)	100 00	
Initiation Fees	(87)	435 00	
			535 00
Advertising		1,440 70	
Sale of Proceedings		248 05	
			1,688 75
Rent			893 00
Buttons			4 00
Junk			54 33
Interest Permanent Fund		201 60	
" Building Fund		43 63	
" Daily Balance		107 51	
			352 74
			$10,406 99

EXPENSES IN DETAIL.

ADMINISTRATION

Secretary's Salary	$1,200 00	
Clerk's Salary	515 00	
Telephone	99 86	
Stationery	153 24	
Postage	215 69	
Express	2 50	
Collector	51 00	
Rent Safe Deposit Box	5 00	
Addressograph	88 00	
Mimeograph	30 00	
Miscellaneous	30 44	
		$ 2,390 73

HOUSE.

Rent	$1,560 00	
Light and Heat	262 81	
Ice Water	22 20	
Water Tax	40 50	
Repairs	34 61	
		$ 1,920 12

LIBRARY.

Printing	$ 4 00	
Binding	186 60	
Express	4 20	
Labor	13 70	
Periodicals	9 26	
		$ 217 76

PROCEEDINGS.

Printing	$2,056 96	
Illustrations	161 84	
Binding	80 85	
Express	35 95	
Stationery	78 50	
Postage	220 21	
Refund of over payments	23 85	
Copyright	6 00	
Miscellaneous	17 39	
		$ 2,681 55

ADVERTISING.

Solicitor, (Salary)	$ 257 50	
Solicitor, (Commission)	108 21	
Legal Services	35 00	
Auditor	10 00	
Printing	7 00	
Postage	8 50	
Miscellaneous	2 95	
		$ 429 16

SOCIETY MEETINGS.

Printing advance copies	$ 97 80	
Copyright	4 00	
Announcements	103 20	
Postage	92 80	
Express	5 00	
Stationery	13 16	
Lantern	10 00	
Lantern Slides	14 80	
Expenses of Lecturers	59 22	
Reporting Meetings	100 00	
		$ 499 98

CHEMICAL SECTION MEETINGS.

Reporting Meetings	$ 10 00	
		$ 10 00

MECHANICAL SECTION MEETINGS.

Printing advance copies	$ 46 75	
Copyright	2 00	
Printing Notices	10 00	
Express	2 00	
Postage	32 23	
Reporting Meetings	80 00	
		$ 172 98

STRUCTURAL SECTION MEETINGS.

Printing notices	$ 10 50	
Postage	30 00	
Lantern	10 00	
Reporting Meetings	80 00	
		$ 130 50

RECEPTION COMMITTEE.

Printing Notices	$ 34 10	
Postage	70 50	
		$ 104 60

MEMBERSHIP LIST.

Printing Notices	$ 160 25	
Postage	32 00	
Stationery	2 00	
		$ 194 25

MISCELLANEOUS.

Initiation Fee, refunded	5 00	
Dues American Society for Testing Materials	5 00	
		$ 10 00
Total		$ 8,761 63

Note:

Total Postage	$ 701 93
" Printing	2,540 26
" Stationery	246 90

The funds of the Society are kept under four separate accounts, all being with the Guarantee Title & Trust Co. The following is a condensed exhibit of the condition of each of these accounts:

Checking Account:

Balance January 1st, 1905	$ 1,936 35	
Dues, Rents, etc.,	10,054 25	
Interest, on Daily Balances	$ 107 51	
		$12,098 11
Disbursements; Operating Expenses	8,761 63	
Transferred to other accounts	2,579 52	
		$11,341 15
Balance		$ 756 98

Building Fund:

Balance January 1st, 1905	$ 1,302 32	
From Checking Account	25 00	
Interest, (Savings Bank)	43 63	
		$ 1,370 95
Bonds purchased, with premium and accrued interest		1,032 78
Balance		$ 338 17

Permanent Fund:

Balance January 1st, 1905	$ 3,617 59	
From Checking Account	2,554 52	
Interest (Savings Bank)	201 60	
		$ 6,373 71
Bonds purchased, with premium and accrued interest		6,171 10
Balance		202 61

Key Fund:

Balance January 1, 1905	$ 25 00
Total Balances	$ 1,322 74

INVESTMENTS.

BUILDING FUND.

	COST.
One, $1,000.00, Butler Water Company, 5% bond, No. 9, matures September 2, 1931	$ 1,025 00

PERMANENT FUND.

Two, $1,000.00, Connellsville Water Company 5% bonds No. 317—318, mature October 1, 1939	2,020 00
Two $1,000.00, Portsmouth, Berkeley & Suffolk Water Company, 5% bonds, No. 465—466, mature November 1, 1944	2,000 00
One, $1,000.00, Manufacturers Light & Heat, 6% bond, No. 42, Series K, matures May 1, 1914	1,010 00
One, $1,000.00, Manufacturers Light & Heat 6% bond, No. 1183, matures September 2, 1909	1,010 00

Respectfully submitted,

A. E. Frost,
Treasurer.

SECRETARY'S REPORT.

Membership January 1, 1905		937
At the Annual Meeting January 5, 1905, there were dropped	6	
Deaths during the year 1905	7	
Resignations	60	
Total loss of	73	
Elected to membership during 1905.....	85	
Of whom there matriculated	78	
Of the applicants elected during the year 1904, there matriculated	8	
Total new members	86	
Net gain		13
Membership January 1, 1906		950
Honorary members	7	
Life Members	2	
Paid 1906	4	
" 1905	793	
		806 good
Owe 1905	76	
" 1904-5	48	
" 1903-4-5	19	
" 1902-3-4-5	1	
		144 delinquent
Back dues owing to Society for 1902...	$ 5 00	
" " " " " " 1903...	138 00	
" " " " " " 1904...	483 00	
" " " " " " 1905...	1,046 00	
Total	$1,672 00	
Average attendance at meetings of the Society		45

COMPARISON BETWEEN YEAR 1904 AND 1905.

Increase in membership	39	13
Per cent increase in membership....	4.4%	1.4%

Average attendance at meetings....	89	45
Per cent members attending.....	10.1%	4.8%
Income	$7,235 63	$10,406 99
Change in income over previous year	—$1,276 69	+$3,171 36
Change in income over previous year	—18.5%	+43.8%
Expenditures	$5,596 25	$8,761 63
Increase over previous year.....	2.6%	56.5%
Surplus	$1,639 38	$1,645 36
Surplus compared with previous year	—52.3%	+2%
Receipts written	832	1,060

Note;

Largest previous income, 1903.....$8,512 32

1905 exceeds it by ..... 1,919 66, or 22.5%

On motion the reports were accepted.

The President then read the report of the Nominating Committee as follows:

President, Julian Kennedy,
Vice-President, J. K. Lyons,
Directors, { E. K. Morse, A. R. Raymer,
Treasurer, A. E. Frost,
Secretary, F. V. McMullin.

There being but one candidate for each office a formal ballot was considered unnecessary, and on motion the Secretary was directed to cast the ballot of the Society for the candidates as read.

The President appointed past Presidents Thos. H. Johnson and Chas. Davis to escort the newly elected President to the chair.

The retiring President then read his address.

On motion a vote of thanks was extended to the retiring officers for their work during the past year.

On motion adjourned at 9:20 P. M.

F. V. McMullin,
Secretary.

MONTHLY MEETING OF SOCIETY.

The 261st regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, 410 Penn Avenue, Pittsburgh, Pa., Tuesday, January 16, 1906, at 8:30 P. M., Vice-President J. K. Lyons in the chair and 48 members and visitors present.

The minutes of the last meeting were read and approved.

The report of the Board of Direction was read, recommending seven applicants for membership.

On motion the Secretary was instructed to cast the ballot of the Society for their election.

The paper for the evening, "The Electrical Transmission of Power over Great Distances," by S. M. Kintner, was read, in the absence of the author, by Chas. F. Scott.

Paper discussed by Frost, Fisher, Flint, Lyons, Flanagan, Campbell and Riddle.

The meeting adjourned at 10:10 P. M.

F. V. McMullin,
Secretary.

NEW MEMBERS JOINED IN JANUARY 1906.

HARRISON E. ASHLEY, Chem. Eng., Homer Laughlin China Co., 154 Pennsylvania Ave., Sta. A, E. Liverpool, Ohio.	J. M. Camp, H. E. Walters, Harrison W. Craver.
SYDNEY S. BAKER, Checker, National Tube Co., McKeesport, Pa. 637 Madison Avenue, McKeesport, Pa.	A. H. Anthony, Alex. L. Hoerr, W. R. Pendry.
ALBERT N. DICK, Assistant Engineer, Bureau of Construction, Pittsburgh, Pa. h. 7604 Hamilton Avenue, Pittsburgh, Pa.	Willis Whited, J. G. Chalfant, Louis E. Vierheller.
HERBERT W. GODDARD, Civil Eng., T. A. Gillespie Company. 800 Westinghouse Building, Pittsburgh, Pa.	W. B. Fuller, Robert Swan, Morris Knowles.
ANDERS JORDAHL, Structural Engineer, American Structural Steel Company. Carnegie, Pa.	O. Hoem, P. Brynn, Franz Engstrom.
FRED OPHULS, Agent, De La Vergne Machine Company. 610 Times Building, Pittsburgh, Pa.	J. R. Kommer, F. V. McMullin, Samuel Diescher.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at the Society's rooms, 410 Penn Avenue, Pittsburgh, Pa., Saturday, January 13th, 1906, at 7:30 P. M.

Present: Messrs. Kennedy, Lyons, Knowles, Barnsley, Morse and Secretary.

The following resignations were accepted:

Hasell W. Baldwin,
P. T. Berg,
H. W. Bernard,
Francis H. Brown,
E. D. Buffum,
John M. Davidson,
E. H. Dewson,
John B. Dimmick,
J. R. Elliott,
Edwin Fickes,
George F. Freed,
C. L. Hastings,
Frank Irwin,
Gustave Kaufman,
L. L. Knox,
Thos. O'C. Jones,
W. T. Manning,
John McLeod,
Dr. Richard Moldenke,
A. C. Munhall,
W. A. Page,
Andrew Pinkerton,
George H. Randall,
Marcus A. Smith,
S. H. Stupakoff,
D. Y. Swaty,
Gaylord Thompson,
C. D. Wettach,
A. W. Wycoff,
George A. Young,

Bills were paid aggregating $717.20.

On motion the services of the Advertising Solicitor were dispensed with.

On motion the Secretary's salary was raised to $1,800.00 per year.

On motion the Secretary was directed to publish no more advance copies.

On motion adjourned at 9:30 P. M.

F. V. McMullin,
Secretary.

CHEMICAL SECTION.

The fourteenth Annual meeting was held at 410 Penn Avenue, January 18, 1906.

The Chairman and Vice-Chairman being absent the meeting organized at 8:30 P. M. by electing Mr. Charles H. Rich chairman *pro tempore*. Fifteen members and visitors were present.

The minutes of the thirteenth Annual meeting were read and approved.

The Secretary read his report, which was accepted.

The list of nominations presented to the Section at the December meeting was read. No other nominations being made, the Secretary was instructed to cast a joint ballot electing the following officers:

Chairman, Lawrence L. Arnold,
Vice-chairman, Jacob A. Mohr,
Secretary, Harrison W. Craver,
Directors, { James M. Camp,
Harry E. Walters.

No other business being presented, the meeting adjourned at 9:00 P. M.

HARRISON W. CRAVER,
Secretary, C. S.

The one hundred and thirty-seventh regular meeting was held at 410 Penn Avenue, after the adjournment of the Annual meeting, Thursday, January 18, 1906, with the Pittsburgh Section of the American Chemical Society.

No business coming before the meeting, an informal discussion occurred, after which the meeting adjourned at 10:00 P. M.

HARRISON W. CRAVER,
Secretary, C. S.

MECHANICAL SECTION.

The regular monthly meeting of the Mechanical Section was held at 410 Penn Avenue, Pittsburgh, Pa., January 7, 1906, at 8:30 P. M., with H. H. Anderson in the chair and 26 members present.

The Nominating Committee submitted the following names as candidates for officers for the ensuing year:

Chairman, Wm. H. Baltzell,
Vice-chairman, L. C. Moore,
Secretary, A. A. Lane,
Directors, { Chester B. Albree, H. H. Anderson.

On motion the Secretary was directed to cast the ballot for the election of the officers. The newly elected Chairman then took the chair, after which G. M. Campbell read a paper on "The Power Required by Machine Tools."

The Discussion which followed was participated in by Messrs. Haslam, Stucki, Baltzell, Anderson and Lane.

On motion the meeting adjourned at 10:10 P. M.

A. A. LANE,
Secretary M. S.

STRUCTURAL SECTION.

Annual Meeting of the Structural Section was held in the Society rooms, 410 Penn Avenue, January 23rd, 1906, with 39 members and visitors present.

Meeting called to order by Chairman, E. K. Morse, at 8:20 P. M.

Minutes of the last Annual Meeting read and approved.

Retiring Chairman, E. K. Morse, read his address, after which officers for the coming year were elected, as follows:

Chairman, Robert A. Cummings,
Vice-Chairman, Thomas D. Lynch,
Secretary, G. H. Danforth,
Directors, { F. M. Bowman, Ralph Crooker, Jr.

Mr. Chester B. Albree was appointed by the chair, a committee of one, to escort Mr. Cummings to the chair.

There being no further business before the Annual Meeting, the Annual Meeting adjourned.

G. H. Danforth,
Secretary S. S.

Regular meeting called to order and Mr. William F. Miller read a paper on Steel Ties, discussion participated in by Messrs. Morse, Porter, McCune, Granville, Mulenhoff, Johnson and Stucki.

On motion the meeting adjourned at 10:25 P. M.

G. H. Danforth,
Secretary S. S.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

Vol. XXII MARCH, 1906 No. 2

MONTHLY MEETING OF SOCIETY.

The 262nd regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, 410 Penn Avenue, Pittsburgh, Pa., Tuesday, February 20, 1906, at 8:10 P. M., Vice-President J. K. Lyons in the chair with 50 members and visitors present.

The minutes of the last meeting being in print, and there being no objections, their reading was dispensed with.

The report of the Board of Direction was read, recommending five applicants for membership.

On motion the Secretary was instructed to cast the ballot of the Society for their election.

The Banquet Committee reported a balance in hand of $51.45, and asked that a resolution be passed granting them the privilege of appropriating this amount toward furnishing the new quarters.

The Committee on New Quarters reported that a lease had been made and executed for a suite of rooms on the eighth floor of the Fulton Building for the home of the Society for three years from the first of April, 1906, at a rental of $2,500.00 per year.

On motion the two reports were accepted and the Reception Committee was authorized to expend the balance left over from the Banquet for furnishing the new rooms.

The paper for the evening on "Bridges" was then read by Mr. Willis Whited.

After reading, the paper was discussed by Messrs, Johnson, Stucki, Umstead, Muellenhoff, Morse, Prichard and Lewis.

On motion adjourned at 10:10 P. M.

F. V. McMullin,

Secretary.

NEW MEMBERS JOINED IN FEBRUARY.

JOHN EDWIN BANKS, Engineer charge Drawing Room, American Bridge Co., 4747 Friendship Ave., Pittsburgh, Pa.	J. K. Lyons, Franz Engstrom, P. Brynn.
ULYSSES GRANT DUVALL, Civil Eng., Miller-Patterson Co., Fourth Ave., Pittsburgh, Pa. h. Chartiers, Allegheny Co., Pa.	F. W. Patterson, W. F. Miller, Geo. T. Barnsley.
EUGENE N. HUNTING, Eng. & Supt., for Robt. A. Cummings, 1018 House Bldg., Pittsburgh, Pa.	Robt. A. Cummings, A. A. Lane, F. V. McMullin.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at the Society's rooms, 410 Penn Avenue, Pittsburgh, Pa., Saturday, February 10, 1906, at 8:15 P. M.

Present: Messrs. Lyons, Knowles, Barnsley, Morse Schellenberg, Cummings and Secretary.

The following resignations were accepted:

Murray C. Beebe,	R. H. McMillen,
H. J. Glaubitz,	W. J. Prentice,
H. O. Jones,	Girard B. Rosenblat.

On motion the President was authorized to sign a lease for the rooms 801, 802, 803, 804, 816, 817 and 818, for a period

of three years, at a rental not exceeding $2,500.00 per year in the new Fulton Building.

Report of the Committee on New By-Laws was presented, and on motion was accepted.

The subject of improving the attendance at the meetings was brought up for discussion but no action was taken beyond directing the Secretary to try to secure the attendance of the Chairmen of the Sections at the next meeting and directing him in the meantime not to recognize any Section Committees.

On motion meeting adjourned at 9:30 P. M.

F. V. McMullin,

Secretary.

CHEMICAL SECTION.

The one hundred and thirty-eighth regular meeting was held with the Pittsburgh Section of the American Chemical Society at 410 Penn Avenue, February 22, 1906.

The meeting was called to order at 8:30 P. M. The Chairman and Vice-Chairman being absent, Mr. H. E. Ashley was elected temporary chairman. 28 members and visitors were present.

The minutes of the last meeting were read and approved.

Mr. C. M. Johnson spoke on the determination of carbon in iron, supplementing his paper read before the Section in December last. Further experiments show that the use of copper oxid in the combustion tube is unnecessary, and its omission is recommended. The advantages are the possibility of using shorter tubes and furnaces, a fifteen-inch tube and five burner furnace being sufficient; and an increased life for the tube, due to more favorable conditions in cooling. Mr. Johnson also favors the use of potassium hydroxid instead of barium hydroxid as an absorbent for the carbon

dioxid, as he finds that time is saved in weighing and filling absorption vessels.

Mr. Earl Blough read a paper on the "Constitution of the Bronzes." This described the results of the study of the structure of a very complete set of copper-tin alloys under various heat treatments. The paper was illustrated with lantern-slides.

In the discussion which followed, Mr. Blough stated that he had found a ten per cent solution of ferric chlorid in alcohol, slightly acidulated with hydrochloric acid, the most satisfactory reagent for etching bronzes, especially for photographic work. Mr. H. E. Walters described an electrolytic method of etching, the specimen being electrolyzed in water containing 0.5 to 1 cc. sulphuric acid for 125 cc. water.

On motion, the meeting adjourned at 10:30 P. M.

HARRISON W. CRAVER,
Secretary.

MECHANICAL SECTION.

The 29th regular meeting of the Mechanical Section was held at the Society's rooms, 410 Penn Avenue, Tuesday, February 6, 1906, at 8:30 P. M.

The meeting was called to order by Vice Chairman L. C. Moore, with 18 members and visitors present.

A paper on "Central Power Stations," was read by F. F. Espenschied.

The paper was discussed by Messrs. James, Stucki, Espenschied, Klindworth, Isreal, Harlow, Campbell, Moore and Lane.

On motion, a vote of thanks was given to Mr. Espenschied for his paper.

Meeting adjourned at 10:30 P. M.

A. A. LANE,
Secretary M. S.

STRUCTURAL SECTION.

The regular monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held Tuesday evening, February 27th, 1906, at the Society's rooms, 410 Penn Avenue, Pittsburgh, Pa.

Twenty-six members and visitors were present.

Meeting called to order by Chairman, R. A. Cummings at 8:20 P. M.

Minutes of the last regular meeting read and approved.

Resignation of Mr. T. D. Lynch, as Vice-Chairman was received and Mr. W. M. Judd was elected to succeed him.

The subject for the meeting was a topical discussion on "Erection Methods for Structural Steel."

The subject was introduced by E. K. Morse, and participated in by Messrs. Bainbridge, Pittman, Wilkerson, Cummings, Mullen, Rice, Swenk, Stucki, Umstead, Bowman, McEwen and Jennings.

On motion meeting adjourned at 10:00 P. M.

G. H. Danforth,
Secretary, S. S.

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OFFICERS FOR 1906.

President.
JULIAN KENNEDY.
Vice-Presidents.
S. M. KINTNER, J. K. LYONS.
Treasurer, A. E. FROST. Secretary, F. V. McMULLIN.
Directors.
MORRIS KNOWLES. E. K. MORSE.
GEO. T. BARNSLEY. A. R. RAYMER.

STANDING COMMITTEES.
Reception Committee.
MORRIS KNOWLES, Chairman.
J. M. CAMP. F. R. DRAVO.
RALPH CROOKER, Jr. E. H. HASLAM.
EMIL GERBER.

Program Committee.
F. Z. SCHELLENBERG, Chairman.
S. M. KINTNER, A. R. RAYMER, J. O. HANDY.
House Committee.
GEORGE T. BARNSLEY, Chairman.
D. W. McNAUGHER, WALTHER RIDDLE.

Library Committee.
D. ASHWORTH, Chairman.
G. W. SCHLUDERBERG. K. F. STAHL. HARRY J. LEWIS.

SPECIAL COMMITTEES.
Publication Committee.
E. K. MORSE, Chairman.
F. S. RICE. L. J. AFFELDER.

Finance Committee
J. K. LYONS, Chairman.
A. E. FROST. G. E. FLANAGAN.

Building Committee.
WILLIS WHITED, Chairman.
WM. METCALF. J. A. BRASHEAR.
THOS. H. JOHNSON. EMIL SWENSSON.
Committee on New By-Laws.
WILLIS WHITED, Chairman.
CHARLES F. SCOTT. KARL F. STAHL.
DANIEL ASHWORTH. F. W. WINTER.

Committee on Timber Tests.
E. K. MORSE, Chairman.
J. A. ATWOOD, THOS. H. JOHNSON, F. Z. SCHELLENBERG,
GEO. T. BARNSLEY, HARRY J. LEWIS, EMIL SWENSSON,
J. N. CHESTER, FRANCIS S. RICE. WILLIS WHITED,
R. A. CUMMINGS, WM. L. SIBERT, T J. WILKERSON.
RALPH CROOKER, Jr., WM. MARTIN.

CHEMICAL SECTION.
LAWRENCE L. ARNOLD, Chairman.
Vice-Chairman, JACOB A. MOHR. Secretary, HARRISON W. CRAVER.
Directors.
J. M. CAMP. HARRY E. WALTERS.

MECHANICAL SECTION.
L. C. MOORE, Chairman.
Vice-Chairman, G. M. CAMPBELL. Secretary, A. A. LANE.
Directors.
CHESTER B. ALBREE. H. H. ANDERSON.

STRUCTURAL SECTION.
ROBT. A. CUMMINGS, Chairman.
Vice-Chairman, W. M. JUDD. Secretary, G. H. DANFORTH.
Directors.
F. M. BOWMAN. RALPH CROOKER, Jr.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

Vol. XXII APRIL, 1906 No. 3

MONTHLY MEETING OF SOCIETY.

The 263rd regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, 410 Penn Avenue, Pittsburgh, Pa., Tuesday, March 20, 1906, at 8:15 P. M., Vice-President S. M. Kintner in the chair with 64 members and visitors present.

The minutes of the last meeting being in print, and there being no objections, their reading was dispensed with.

The report of the Board of Direction was read, recommending nine applicants for membership.

On motion the Secretary was instructed to cast the ballot of the Society for their election.

On behalf of the Reception Committee, Mr. Knowles announced that there would be an opening night in the new quarters, date to be announced. He also requested any member learning of desirable points of interest which the Society should visit, to inform either the Secretary or himself.

The paper for the evening on "Technical Photography" was then read by Mr. Frederick Henius, presenting many lantern illustrations.

On motion adjourned at 10:30 P. M.

F. V. McMullin,

Secretary.

NEW MEMBERS JOINED IN MARCH.

A. W. KUTSCHE, Gen. Supt. Construction, Carnegie Institute, Pittsburgh Pa. h. Elwood and Summerlea Sts., Pittsburgh, Pa.	Richard Khuen, P. Brynn, Frans Engstrom.
HERBERT HENDERSON, Civil Eng., The Hindman-Henderson Co, 245 Fourth Ave., Pittsburgh, Pa.	F. V. McMullin, Willis Whited, Geo. H. Prosser.
WILLIAM W. CLARK JR., Master Mech., Monongahela Casting Co., Monongahela City, Pa.	Charles V. Slocum, Louis B. Whitney, Geo. T. Barnsley.
FRANK F. McCLINTOCK, Director, Chester B. Albree Iron Works. h. 805 Amberson Avenue, Pittsburgh, Pa,	Samuel B. Ely, Chester B. Albree, Ralph Albree.
WILLIAM A. CHRISTIAN, U. S. Ass't Engineer, Dam Construction Ohio River, Wheeling, W. Va.	W. H. Chadbourn, Jr., Robt. Swan, F. V. McMullin.
HARRY BAINBRIDGE, Supt. Struc. Dept., Jones & Laughlin Steel Co., Pittsburgh, Pa. h. 104 S. 24th St., Pittsburgh, Pa.	G. H. Danforth, F. L. Garlinghouse, John L. Haines.
FRANK NEWMAN SPELLER, Met. Eng., National Tube Company, 1821 Frick Building, Pittsburgh, Pa.	P. C. Patterson, Alex. C. Newlin, G. H. Winslow.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at the Society's rooms, 410 Penn Avenue, Pittsburgh, Pa., Saturday, March 10, 1906, at 8:15 P. M.

Present: Messrs. Kintner, Lyons, Knowles, Barnsley, Morse, Schellenberg, Moore and Secretary.

The following resignations were accepted:

R. E. Cecil,
John S. Holliday,
Zenas H. Sikes,

The following deaths were reported:

Per Brynn,
J. Mont McCrickart.

The Secretary submitted a statement showing that the

total amount of advertising in the Proceedings was increasing and that the advertising was becoming more profitable to the Society.

On motion the following prices for Proceedings were adopted, the same to apply to those bought by authors over and above the 25 free copies supplied them.

1 to 10 copies,	50c	apiece.
10 to 50 copies,	35c	"
50 to 100 copies,	25c	"
500 and above,	20c	"

On motion the action of the President in inviting the Ohio Society of Mechanical, Electrical and Steam Engineers to hold their spring meeting in the Society's rooms, was approved.

The subject of improving the Society meetings was discussed and it was decided that all business excepting the election of members should be eliminated from such meetings.

The House Committee reported that the building would hardly be ready for occupancy by April 3rd, and on motion the Secretary was directed to notify the Chairman of the Mechanical Section and request him not to arrange for a meeting of the Section in April.

On motion the Reception Committee was authorized to spend not over $250.00 for entertainment at a house-warming in the new quarters.

On motion adjourned at 10:20 P. M.

F. V. McMullin,

Secretary.

SPECIAL MEETING OF BOARD OF DIRECTION.

A special meeting of the Board of Direction for the purpose of considering a revision of the Charter and changes in the By-Laws, was held at the Society's rooms, 410 Penn Avenue, Pittsburgh, Pa., March 17, 1906, at 3:10 P. M.

Present: Messrs. Kennedy, Kintner, Lyons, Knowles, Barnsley, Morse, Raymer, past President Scott and Secretary.

On motion it was decided to confine discussion to changes in Charter.

On motion the preamble and first three Articles were adopted as they had been in the original Charter.

On motion new Articles IV, V, VI, VII and VIII were adopted.

On motion the Secretary was directed to see a lawyer and have Charter drafted in accordance with the desires of the Board.

On motion adjourned at 5:45 P. M.

F. V. McMullin,
Secretary.

CHEMICAL SECTION.

The one hundred thirty-ninth regular meeting was held with the Pittsburgh Section of the American Chemical Society at 410 Penn Avenue, Thursday, March 22, 1906.

The meeting was called to order at 8:30 P. M. by Dr. James, thirty-four members and visitors being present.

Dr. William A. Noyes, Chemist to the Bureau of Standards, Washington, addressed the meeting on "The Work of the Bureau of Standards."

On motion the meeting adjourned at 10:30 P. M.

Harrison W. Craver,
Secretary.

STRUCTURAL SECTION.

The regular monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held Tuesday, March 27, 1906, at the Society's rooms, 410 Penn Ave., Pittsburgh, Pa.

The meeting was called to order by Chairman R. A. Cummings at 8:40 P. M., twenty-two members and visitors being present.

Minutes of the last meeting were read and approved.

There being no committee reports, unfinished or new business, the Chairman introduced the speaker of the evening, Mr. W. N. Kratzer, who spoke regarding "Some Points in the Manufacture of Ornamental Iron Work."

The discussion that followed was participated in by Messrs. Albree, Beuchle, Bissell, Henderson, Muellenhoff, Moore, Kratzer and Jennings.

On motion, meeting adjourned at 10:10 P. M.

G. H. Danforth,

Secretary.

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OFFICERS FOR 1906.

President.
JULIAN KENNEDY.
Vice-Presidents.
S. M. KINTNER, J. K. LYONS.
Treasurer, A. E. FROST. Secretary, F. V. McMULLIN.
Directors.
MORRIS KNOWLES. E. K. MORSE.
GEO. T. BARNSLEY. A. R. RAYMER.

STANDING COMMITTEES.

Reception Committee.
MORRIS KNOWLES, Chairman.
J. M. CAMP. F. R. DRAVO.
RALPH CROOKER, Jr. E. H. HASLAM.
EMIL GERBER.

Program Committee.
F. Z. SCHELLENBERG, Chairman.
S. M. KINTNER, A. R. RAYMER, J. O. HANDY.

House Committee.
GEORGE T. BARNSLEY, Chairman.
D. W. McNAUGHER, WALTHER RIDDLE.

Library Committee.
D. ASHWORTH, Chairman.
G. W. SCHLUDERBERG K. F. STAHL. HARRY J. LEWIS.

SPECIAL COMMITTEES.

Publication Committee.
E. K. MORSE, Chairman.
F. S. RICE. L. J. AFFELDER.

Finance Committee
J. K. LYONS, Chairman.
A. E. FROST. G. E. FLANAGAN.

Building Committee.
GEO. S. DAVISON, Chairman.
WM. METCALF. J. A. BRASHEAR.
THOS. H. JOHNSON. EMIL SWENSSON.

Committee on New By-Laws.
WILLIS WHITED, Chairman.
CHARLES F. SCOTT. KARL F. STAHL.
DANIEL ASHWORTH. F. W. WINTER.

Committee on Timber Tests.
E. K. MORSE, Chairman.
J. A. ATWOOD, THOS. H. JOHNSON, F. Z. SCHELLENBERG,
GEO. T. BARNSLEY, HARRY J. LEWIS, EMIL SWENSSON,
J. N. CHESTER, FRANCIS S. RICE. WILLIS WHITED,
R. A. CUMMINGS, WM. L. SIBERT, T. J. WILKERSON.
RALPH CROOKER, Jr., WM. MARTIN.

CHEMICAL SECTION.
LAWRENCE L. ARNOLD, Chairman.
Vice-Chairman, JACOB A. MOHR. Secretary, HARRISON W. CRAVER.
Directors.
J. M. CAMP. HARRY E. WALTERS.

MECHANICAL SECTION.
L. C. MOORE, Chairman.
Secretary, A. A. LANE.
Directors.
CHESTER B. ALBREE. H. H. ANDERSON.

STRUCTURAL SECTION.
ROBT. A. CUMMINGS, Chairman.
Vice-Chairman, W. M. JUDD. Secretary, G. H. DANFORTH.
Directors.
F. M. BOWMAN. RALPH CROOKER, Jr.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

Vol. XXII MAY, 1906 No. 4

MONTHLY MEETING OF THE SOCIETY.

The 264th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Tuesday, April 24, 1906, at 8:20 P. M., Vice-President S. M. Kintner in the chair with 37 members and visitors present.

The minutes of the last meeting being in print, and there being no objections, their reading was dispensed with.

The report of the Board of Direction was read, recommending 15 applicants for membership.

On motion the Secretary was instructed to cast the ballot of the society for their election.

The paper for the evening, on "The Briquetting of Lignite Coal," was read by Mr. K. A. Muellenhoff.

On motion adjourned at 10:30 P. M.

F. V. McMULLIN,
Secretary.

NEW MEMBERS JOINED IN APRIL.

CHAS. E. PETTEE, Gen. Foreman, Westinghouse Machine Co,, E. Pittsburgh, Pa. h. 725 N. St. Clair St., Pittsburgh, Pa.	Henry W. Fisher, A. E. Duckham, F. V. McMullin.
HENRY R. EDGECOMB, Foreman, Generator Drawing Office, Westinghouse Elec. & Mfg. Co. h. 1311 A. Walnut St., Edgewood Park., Pa.	Henry D. James, Gustave Berentsen, R. S. Feicht.
Wm. O. Brosius, Mech. Engineer, Heyl & Patterson, Pittsburgh Pa. h. 602 Whitney Avenue, Pittsburgh, Pa.	J. L. Klindworth, G. E. Flanagan, George K. Newbury.
MARTIN A. PRESTON, Draftsman, American Bridge Company, Ambridge, Pa. P. O. Box No. 8, Ambridge, Pa.	John Blodgett, P. Brynn, J. K. Lyons.
R. T. McCORMICK, Mgr. Pgh. Offiice, Petroleum Iron Works Co., Farmers Bank Bldg., Pittsburgh, Pa. h. 310 Hay St., Wilkinsburg, Pa.	Daniel Carhart, Chas. W. Ridinger, Albert E. Frost.
GEO. F. BAINBRIDGE, Manager, William Kratzer & Co. 3251 Wilmot St., Pittsburgh, Pa.	Wm. N. Kratzer, G. H. Danforth, F. L. Garlinghouse.
OSCAR L. GERWIG, Chief Draftsman, Thomas Carlin's Sons Co. h. No. 3 Rodgers Avenue, Bellevue, Pa.	M. C. Blest, A. C. Knickerbocker, F. R. Jennings.
CHAS. H. UMSTEAD, Supt. Construction, Construction of U. S. Public Buildings, Washington, Pa.	Willis Whited, G. H. Danforth, F. Z. Schellenberg.

BOARD OF DIRECTORS.

The regular Monthly meeting of the Board of Direction was held at the Society's rooms, Fulton Building, Friday, April 13, 1906, at 8:25 P. M.

Present: Messrs. Lyons, Barnsley, Knowles, Morse, and Secretary.

Minutes of the last regular and special meeting were approved as corrected.

The resignations of Robert C. Falconer and Edwin E. Rushton were accepted.

On motion the Board approved the action of the President and the Chairman of the Publication Committee in entering into an agreement March 29, 1906, with Mr. F. A. Ensign by which, in consideration of a payment of $100.00, Mr. Ensign transferred to the Society all his interest in the advertising appearing in the Proceedings.

On motion the cost of reprints of papers read before the Society, to parties desiring to purchase same in quantities, was placed at cost, plus 25%.

On motion adjourned at 11:20 P. M.

F. V. McMULLIN,
Secretary.

PROCEEDINGS OF THE
ENGINEERS SOCIETY
OF WESTERN PENNSYLVANIA

Published Monthly, 10 Months of the Year. Edited by the Secretary under the direction of the Publication Committee.

Reprints from this publication, which is copyrighted, may be made by any other publication on condition that the full title of paper, name of author, page reference, and date of presentation to the Society are given.

No paper read before the Society shall be published in any magazine or journal before its appearance in the Proceedings, and no paper previously published shall be published in the Proceedings without the sanction of the Board.

The Board reserves the right of supervision of papers and illustrations.

The Society will mail monthly, except August and September, to its members, correspondents and advertisers, postage prepaid, a copy of the Proceedings; each one containing the minutes of and the papers read at the regular meeting and meetings of the Chemical, Mechanical and Structural Sections.

An author of a paper is entitled to 25 copies of the Proceedings containing his paper.

The Proceedings are for sale at the following prices:

1 to 10	copies,	50c	apiece.
10 " 50	"	35c	"
50 " 500	"	25c	"
500 and over		20c	"

Subscription price $5.00 per annum. To colleges and public libraries who agree to bind and catalog, subscription price is $1.00 per annum.

Back volumes are for sale at the following price: Volumes 1, 5, 6, 7, 8, 9, 10, paper bound, $2.00; cloth bound, $2.75.

Sets of Volumes 11, 12, 13, 14, 15, 16 ready for binding, $2.00; bound in cloth, $2.75.

Volumes 18, 19, 20, ready for binding, $5.00; cloth bound, $5.75.

Volumes 2, 3, 4, 17, cannot be furnished.

ADVERTISING RATES PER YEAR

	One page.	½ page.	¼ page.	⅛ page.
Inside front Cover, Outside back Cover,	$180.00	$108.00	$65.00	$40.00
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Inside pages	100.00	60.00	36.00	21.00

Professional Cards, $10.00.

Address all inquiries regarding advertising to the Engineers' Society of Western Pennsylvania, 410 Penn Avenue, Pittsburg, Pa.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

VOL. XXII JUNE, 1906 No. 5

MONTHLY MEETING OF THE SOCIETY.

The 265th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Tuesday, May 15th, 1906, at 8:15 P. M.

The meeting was called to order at 8:15 P. M. by President Kennedy, 70 members and visitors being present.

The minutes of the last meeting were read and approved.

The report of the Board of Direction was read, recommending six applicants for membership.

On motion the Secretary was instructed to cast the ballot of the Society for their election.

The paper for the evening, on "The South Pittsburgh Water Company's New Filter Plant and Pumping Station, and Filtration Generally," was read by Mr. J. N. Chester. The paper was illustrated by a number of lantern slides.

On motion adjourned at 10:30 P. M.

F. V. McMULLIN,
Secretary.

NEW MEMBERS JOINED IN MAY.

A. A. Baker, Draftsman, National Tube Co. 728 Monticello St., Pittsburgh, Pa.	Henry C. Cronemeyer, Alex. L. Hoerr, A. H. Anthony.
Geo. W. Biggs, Jr., Chief Draftsman, American Water Works & Guarantee Co. 714 East End Ave., Pittsburgh, Pa.	M. Knowles, J. N. Chester, Walther Riddle.
Ira W. Dye, Chainman Maintenance of Way Corps, P. & L. E. R. R. Co. h. 1005 Eighth Ave., Beaver Falls, Pa.	Robert M. Pearce, R. T. McMaster, Samuel Reid.
Thos. H. McGraw, Dist. Sales Manager, Erie City Iron Works, 1230 Park Building, Pittsburgh, Pa.	Paul L. Hay, Samuel Diescher, Samuel E. Diescher.
John L. Mullin, Contractor, Erection of Structural Iron Works, 515 Times Building, Pittsburgh, Pa.	G. H. Danforth, F. L. Garlinghouse, Robt. A. Cummings.
Chas. C. Paschedag, Dist. Engineer, Allis-Chalmers Co., 812 Frick Building, Pittsburgh, Pa.	W. C. Hawley, J. W. Murray, Chas. L. Fox.
Ray D. Smith, General Manager, Engineering Agency of Chicago, 828 Fulton Building, Pittsburgh, Pa.	F. V. McMullin, James K. Lyons, E. K. Morse.
L. A. Starrett, Engineering Dept., Rust Boiler Co., Box 541, h. 222½ Ulysses St., Pittsburgh, Pa.	Chas. F. Scott, C. E. Skinner, E. K. Morse.
Clyde Taylor, Structural Department, John Eichleay, Jr., Co., h. 408 West St., Wilkinsburg, Pa.	G. H. Danforth, John Haines, F. L. Garlinghouse.
Leonard J. Wilson, Chief Draftsman, Republic Department, National Tube Co. h. 909 Huey St., McKeesport, Pa.	Henry C. Cronemeyer, Alex L. Hoerr, A. H. Anthony.
C. L. Woolridge, Mechanical Engineer, T. A. Gillespie Co. h. 125 S. Lang Ave., Pittsburgh, Pa.	Wm. B. Fuller, Robt. Swan, Frank Wilcox.
Clarence B. Watkins, Builder & Contractor, 238 Fourth Ave., Pittsburgh, Pa.	H. P. McClintock, H. M. Wilson, A. A. Lane.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Saturday, May 5, 1906, at 8:30 P. M.

Present: Messrs. Kennedy, Kintner, Lyons, Barnsley and Secretary.

On motion it was ordered that in future membership lists should be printed annually at such time that they could be mailed in July.

The House Committee reported the following rules for the government of the rooms and on motion they were approved.

1. The rooms are open for the use of members from 9 o'clock A. M. to 9 o'clock P. M. every day except Sundays, Fourth of July, Thanksgiving day, Christmas day, and on meeting nights, when they will be closed after adjournment.

2. Entrance to these rooms shall be through the Secretary's office except on meeting nights or special occasions, when all rooms may be reached direct from the corridor.

3. Membership cards must be shown when members are not recognized by the Secretary or employee.

4. Visitors will be admitted when introduced by members in person or by letter. The same person shall not enjoy the privilege of the rooms more than once each month. They shall be registered in a book provided for the purpose; the member introducing shall be held responsible.

5. There shall be no card playing or gambling of any description in these rooms.

6. No books, papers, periodicals, magazines, or any other property whatsoever shall be taken from these rooms without proper authority.

7. Eating will not be permitted in the Reception, Reading and Board rooms. When luncheon or other refreshment is served, it must be confined to the auditorium.

On motion the House Committee was authorized to have the rules printed and framed and placed in the rooms.

On motion the House Committee was authorized to secure a registry book for visitors.

On motion adjourned at 10:50 P. M.

F. V. McMULLIN,
Secretary.

MECHANICAL SECTION.

The regular monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, Fulton Building, Tuesday, May 1, 1906, at 8:25.

The meeting was called to order by Vice-Chairman C. B. Albree, 31 members and visitors being present.

The Chairman made an announcement of the resignation of Mr. G. M. Campbell, as Vice-Chairman of the Section, made necessary by his leaving the city. As the By-Laws provide for the filling of the place of Vice-Chairman by the senior director, Mr. Albree becomes Vice-Chairman of the Mechanical Section.

The paper for the evening, on "Compressed Air," was then read by Mr. L. I. Wightman.

The discussion which followed the reading of the paper was participated in by Messrs. Albree, Hunter, Stucki, Stahl, Cronemeyer and Lane.

On motion adjourned at 10:00 P. M.

A. A. LANE,
Secretary M. S.

STRUCTURAL SECTION.

The regular monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held Tuesday, May 22, 1906, at the Society's rooms, Fulton Building, Pittsburgh, Pa.

The meeting was called to order by Chairman R. A. Cummings, at 8:30 P. M., 20 members and visitors being present.

Mr. E. W. Pittman read a paper on the "Construction of Coke and Ore Bins."

The discussion which followed the reading of the paper was participated in by Messrs. Dempsey, Stucki, Muellenhoff, Whited, Crooker, Donaldson, Klindworth and Littell.

On motion adjourned at 9:50 P. M.

G. H. DANFORTH,
Secretary S. S.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

Vol. XXII JULY, 1906 No. 6

MONTHLY MEETING OF THE SOCIETY.

The 266th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Tuesday, June 19, 1906, at 8:15 P. M.

The meeting was called to order by Vice-President Kintner, 37 members and visitors being present.

The minutes of the last meeting being in print, their reading was dispensed with.

The report of the Board of Direction was read, recommending 14 applicants for membership.

On motion the Secretary was directed to cast the ballot of the Society for their election.

The paper for the evening, on "The Laying of Deep Sea Cables," was then read by Mr. H. C. Specht. The paper was illustrated with a number of lantern slides. Paper was discussed by Messrs. Fisher, Smyth, Stucki, Muellenhoff and Kintner.

On motion meeting adjourned at 10:15 P. M.

F. V. McMullin,
Secretary.

NEW MEMBERS JOINED IN JUNE.

BELDEN, SANFORD BONNER, Mgr. Pittsburgh Office Jeffrey Mfg. Co., 1709 Farmers Bank, Pittsburgh, Pa.	H. K. Hitchcock, Geo. H. Deike, J. W. Cordes.
BOLLINGER, FRANK F., Engineer and Contractor, Bollinger Bros., Fulton Building, Pittsburgh.	G. H. Danforth, John L. Haines, F. L. Garlinghouse.
CRANNELL, EARLE SIDNEY, American Locomotive Company, Allegheny, Pa.	H. P. McClintock, C. B. Watkins, H. M. Wilson.
HAMPTON, W. M., Mechanical Engineer, Westinghouse Machine Co., E. Pittsburgh. h. 712 Summerlea St., Pittsburgh, Pa.	William Bradford, Edwin Yawger, E. S. McClelland,
GODFREY, EDWARD, Struct. Engineer, Robert W. Hunt & Co., Pittsburgh, Pa. h. 630 Kirtland Street, Pittsburgh, Pa.	W. L. Shaw, D. W. McNaugher, H. Gulick,
GOODRICH, JOHN WALKER, Representative, The Goheen Mfg. Co.. 910 Empire Building, Pittsburgh, Pa.	Saml. A. Benner, A. R. Raymer, F. V. McMullin,
LEIPOLD, ROBERT T., Designing Dept., American Bridge Company, Frick Bldg. h. Ambridge, Pa.	Louis J. Affelder, Richard Khuen, T. J. Wilkerson,
McNULTY, P. C., Jr., Borough Engineer, Edgewood, Pa. h. 226 West Swissvale Ave., Edgewood Park, Pa.	Walter Rachals, Julian Kennedy, Chas. F. Scott.
NELSON, JAMES A., Mechanical Engineer, T. A. Gillespie Co., Westinghouse Building, Pittsburgh.	W. B. Fuller, Robt. Swan, Frank Wilcox.
ORD, WM., Salesman, Rust Boiler Company, 605 German National Bank Bldg., Pittsburgh.	Edw. Wurts, Morgan W. Hall, W. E. Dickson.
RIDER, FRANK A., Representative, The Jeffrey Manufacturing Co., 1709 Farmers Bank Bldg., Pittsburgh.	H. K. Hitchcock, Geo. H. Deike, J. W. Cordes.
WEIDEMAN, EINAR, Draftsman, Herman Laub, 610 Lewis Block, Pittsburgh.	O. Hoem, A. Jordahl, F. V. McMullin.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Saturday, June 9th, 1906, at 8:10 P. M.

Present: Messrs. Kintner, Lyons, Knowles, Barnsley and Secretary.

The resignations of P. A. Lange and George L. Collard were accepted.

The death of Raymond D. Hall was reported.

On motion the Secretary was directed to purchase a Standard Dictionary.

On motion the Secretary was directed to purchase from the Carnegie Library of Pittsburgh 500 extra copies of the Index to the Society's Proceedings which has been compiled by Mr. Harrison W. Craver.

On motion it was decided to present the Technical Society of the Pacific Coast with a set of the Society's Proceedings to replace those destroyed by the earthquake and fire.

On motion it was decided that in the future no names should be attached to any of the notices appearing in the monthly Announcement of the Society. The Secretary was directed to restrict the Announcement to four pages if possible, if necessary leaving off the page of officers' names.

On motion it was decided to close the rooms at 6:00 P. M. during July and August.

On motion adjourned at 10:15 P. M.

F. V. McMullin,
Secretary.

SPECIAL MEETING OF THE BOARD OF DIRECTION.

A special meeting of the Board of Direction for the purpose of considering proposed changes in the Charter and By-Laws was held at the rooms in the Fulton Building Tuesday, June 12, 1906, at 8:30 P. M.

Present: Kintner, Knowles, Barnsley, Raymer and Secretary.

After discussion, the revised Charter with the exception of Article VI. was considered to be correct and the Secretary was directed to see a lawyer to enquire regarding that Article.

On motion Article I. of the By-Laws was approved as corrected.

On motion adjourned at 10:30 P. M.

F. V. McMullin,
Secretary.

CHEMICAL SECTION.

The 141st regular meeting was held with the Pittsburgh Section of the American Chemical Society, at the Society's rooms in the Fulton Building, June 21, 1906, at 8:30 P. M.

In the absence of the Chairman, the meeting was called to order by Dr. F. C. Phillips, 20 members and visitors being present.

The minutes of the last meeting were read and approved.

Dr. Phillips called the attention of the Section to the serious illness of Mr. James M. Camp, an active member of the Section since its foundation. On motion, the Secretary was instructed to convey to Mr. Camp the heartfelt sympathy of the meeting and its earnest hope of his speedy restoral to health.

Mr. James O. Handy addressed the meeting on "Prospecting for Silver-Bearing Minerals." The discussion which followed was participated in by Messrs. F. C. Phillips. P. D. Chamberlain, H. E. Myers, J. H. James and K. F. Stahl.

On motion the meeting adjourned at 9:40 P. M.

C. H. Rich,
Secretary pro tem.

MECHANICAL SECTION.

The regular monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, Fulton Building, Tuesday, June 5, 1906, at 8:30 P. M.

The meeting was called to order by C. Ludlow Livingston, 30 members and visitors being present.

The paper for the evening, on "Warren-Jamestown Gas Engine Electric Power Plant," was then read by Mr. J. R. Bibbins.

The discussion which followed the reading of the paper was participated in by Messrs. Cronemeyer, Bibbins, Muellenhoff, Rutherfoord, Danforth, Scheile, Stucki, Chapman and Lane.

On motion adjourned at 10:00 P. M.

A. A. Lane,
Secretary M. S.

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PER BRYNN.

Per Brynn was born at Modum, Norway, February 21st, 1866. He received his early education in a private school at the place of his birth. Later he attended the high school at Drammen, from which he was graduated with high honors in 1882. He then entered the Technological Institute at Trondhjem, from which he received the degree of M. E. in 1886. The following year was devoted to a post-graduate course in Civil Engineering in the same Institution.

In 1887 Mr. Brynn came to America and entered the service of the Shiffler Bridge Co., of Pittsburgh, in the capacity of draftsman and estimator. In January, 1894, he was placed in charge of the annex to the company's main drawing room, where he remained until August, 1898, when he was promoted to the charge of the Philadelphia branch office. In June of the following year he was recalled to Pittsburgh and appointed chief draftsman for the company.

When the Shiffler Bridge Co. was taken over by the American Bridge Co. in May, 1900, Mr. Brynn was placed in charge of one of the structural departments of the latter company, where he remained until the time of his death.

Mr. Brynn was a man who left the impress of his personality on all who met him. One felt immediately that he was worth knowing, an impression that association only strengthened and confirmed. He was always dignified and reserved, unassuming in manners and thoughtful of others. Sincerity of purpose and faithful effort characterized his whole work and gained for him the high regard of all who knew him.

On February 1st, 1906, Mr. Brynn was married to Mrs. Josephine Opsion, of Pittsburgh. Just ten days later, while still on their wedding trip, he passed away in New York City. He is survived by his wife, his mother and three sisters who reside at Drammen, Norway, and two brothers, Mr. Anders Brynn, of Christiana, Norway, and Mr. Soeren Brynn, of Pittsburgh.

Mr. Brynn became a member of the Engineers' Society of Western Pennsylvania in March, 1892.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

Vol. XXII OCTOBER, 1906 No. 7

MONTHLY MEETING OF SOCIETY.

The 267th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Tuesday, September 18, 1906, at 8:25 P. M.

As all the officers of the Society, except the Secretary, were absent, past-President W. A. Bole presided, 30 members and visitors being present.

The minutes of the last meeting being in print, their reading was dispensed with.

The report of the Board of Direction was read, recommending eight applicants for membership.

On motion the Secretary was directed to cast the ballot of the Society for their election.

The paper for the evening, "Dissipation of Heat as Applied to the Annealing of Plate Glass," was then read by Mr. H. K. Hitchcock. The discussion which followed the reading of the paper was participated in by Messrs. Bole and Starrett.

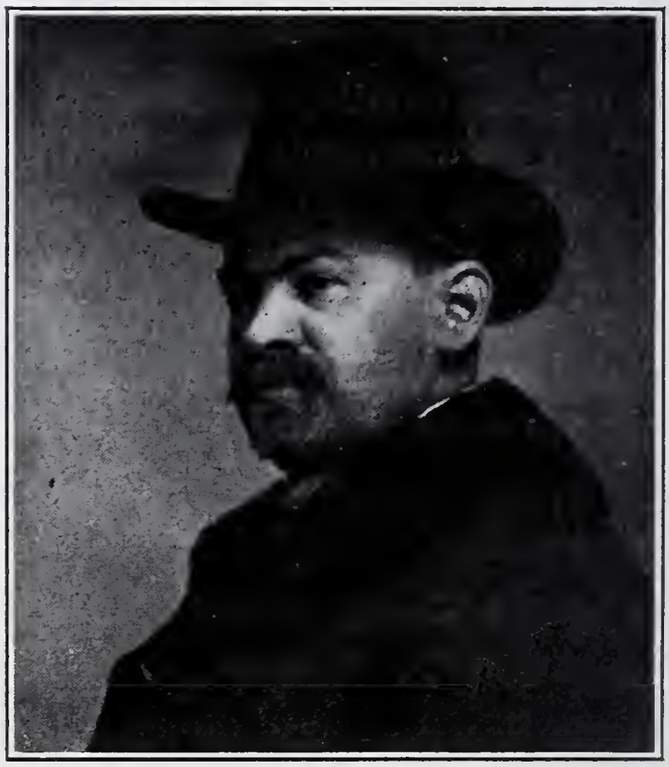
On motion the meeting adjourned at 10:00 P. M.

F. V. McMullin,
Secretary.

CAMILLE MERCADER.

Camille Mercader was born November 24, 1862, in Hyitra, Hungary; died September 7, 1906, at St. Joseph's hospital, Philadelphia, from the effects of a blood clot on the brain.

He was educated at the preparatory school in his native town, the technical school at Chemnitz, Saxony,



CAMILLE MERCADER.

and the Polytechnic school at Dresden, where he graduated in mechanical engineering in 1884. The years from 1884 to 1888 were spent with Prof. Linde at Wiesbaden, an authority on ice machines; later he was connected with Mr. Siemens, in London.

He came to the United States in 1889, going first to Milwaukee and then to Chicago, where he worked for

Abram Gottlieb, formerly President of the Keystone Bridge Co., and a past President of the Engineers' Society of Western Pennsylvania.

He entered the employ of the Carnegie Steel Company in 1890, where he was made engineer of the Edgar Thompson Works. In this position he made use of and broadened his knowledge of the various branches of engineering.

From 1896 to 1898 he designed and erected one of the largest steel plants in Hungary. He returned to the United States in 1898 and was made Assistant to the President of the Carnegie Steel Company for special work.

He had a great number of patents, among which the Hollow Axles and the Rolled Steel Wheels are the most important.

In 1903 he read a paper before the Iron and Steel Institute, London, on Hollow Axles, and his ideas were endorsed by no less an authority than Prof. Reuleux.

Mr. Mercader is survived by three brothers and two sisters in Hungary. He was never married.

He had been President of the German Technical Society, was a member of the British Iron and Steel Institute, the Art Society of Pittsburgh and several clubs. He became a member of this Society in September, 1890.

Everywhere, and especially in Pittsburgh, he had a large number of friends who were very much attached to him on account of his unselfish manner and noble character, and he will be missed for a long time in all the circles where he was active.

NEW MEMBERS JOINED IN JULY, 1906.

CARNAHAN, WILLIAM CUMMINGS, Supt. Bellaire Works, Carnegie Steel Co.	Wm. Siddall, J. H. McDonald, Louis H. McDonald.
COLEMAN, JOHN N., Member of Firm, Cosmopolitan Engineering Co., House Building, Pittsburgh.	G. H. Danforth, John L. Haines, F. L. Garlinghouse.
HOKANSON, B. M., Civil Engineer, J. A. Gillespie Co., Aspinwall, Pa.	Richard Khuen, P. Brynn, Frans Engstrom.

NEW MEMBERS JOINED IN AUGUST, 1906.

CARRELL, W. A., Supt. Mech. Department, H. J. Heinz Co., h., 63 Sprague avenue, Bellevue, Pa.	W. O. Brosius, Wm. L. Fewsmith, George Mesta.
ELDER, PAUL G., Mining Engineer, Pittsburg Plate Glass Co., Tarentum, Pa.	H. K. Hitchcock, George H. Deike, J. W. Cordes.

NEW MEMBERS JOINED IN SEPTEMBER, 1906.

DOUGLAS, HENRY T., Jr., Chief Engineer, Wabash Railroad, Pittsburgh, Pa.	A. R. Raymer, E. K. Morse, J. A. Atwood.
HOWARD, CHARLES P., Civil and Consulting Engineer, 704 Empire Building, Pittsburgh.	A. R. Raymer, E. K. Morse, J. A. Atwood.
LOOMIS, ELMER G., Supt. Bureau of Electricity, City of Allegheny, 1335 Kentucky avenue, Allegheny, Pa.	R. S. Orr, H. W. Fisher, James O. Handy.
STEVENSON, PAUL V., Manager Pittsburgh Office Morse Chain Co. Westinghouse Building, Pittsburgh.	George H. Deike, H. K. Hitchcock, P. G. Elder.
VANDEVORT, N. A., Expediter, 402 Times Building, Pittsburgh, Pa.	J. K. Lyons, E. A. Amaden, J. E. Banks.
WATSON, CHAS. P., President Watson Ordnance Co., h., 913 Irwin avenue, Allegheny, Pa.	J. E. Whittlesey, W. N. Chadbourn, Jr., George T. Barnsley.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Tuesday, July 25, 1906, at 8:30 P. M.

Present: Messrs. Knowles, Barnsley, Morse, Schellenberg and Secretary.

The resignations of W. H. Chadbourn, Jr., and H. B. Robinson were accepted.

The death of I. V. Hoag, Jr., was reported.

A letter from the Technical Society of the Pacific Coast was read, thanking the Society for a set of the Society's "Proceedings."

On motion the acknowledgement to the Carnegie Library for the Index to the Society's "Proceedings," which the Secretary proposed to print in the back of the cover, was approved.

On motion adjourned at 10:15 P. M.

F. V. McMullin,
Secretary.

SPECIAL MEETING OF THE BOARD OF DIRECTION.

A special meeting of the Board of Direction for the purpose of transacting routine business and considering the revised Charter and By-Laws, was held at the Society's rooms, Fulton Building, Pittsburgh, Pa, Friday, August 17, 1906, at 8:15 P. M.

Present: Messrs. Kintner, Lyons, Knowles, Morse, Raymer and Secretary.

On motion the Secretary was directed to express the thanks of the Society to the officers of the Carnegie Steel Co., H. K. Porter Co., and the Riter-Conley Mfg. Co. for the courtesies extended to the members on the occasion of their visits of June 16th, July 21st and August 15th.

On motion the proposed application blank and reference blank submitted by the Secretary were approved.

On motion the second draft of the revised Charter made by the attorney, was approved.

On motion Article I. of the By-Laws was approved as amended.

On motion Article II. of the By-Laws was approved as amended.

On motion Article III. of the proposed By-Laws was approved as amended.

On motion adjourned at 11:45 P. M.

F. V. McMULLIN,
Secretary.

SPECIAL MEETING OF THE BOARD OF DIRECTION.

A special meeting of the Board of Direction, for the purpose of considering the revised Charter and By-Laws, was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Thursday, August 23, 1906, at 8:00 P.M.

Present: Messrs. Kintner, Lyons, Knowles, Barnsley, Morse, Raymer and Secretary.

On motion Article IV. of the new By-Laws was approved as amended. Article V., with the exceptions of Sections 8 and 9, which the Secretary was directed to re-write, was approved as amended. Articles VI., VII. and IX. were approved as amended.

On motion the Secretary was directed to convey to the Committee on new By-Laws the thanks of the Board for the conscientious manner in which they had performed their duties, and to notify them that the Committee was now dismissed.

On motion adjourned at 11:15 P.M.

F. V. McMULLIN,
Secretary.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was called for the evening of Saturday, September 8, 1906. But two members appearing, Messrs. Kintner and Barnsley, no business could be transacted.

F. V. McMullin,
Secretary.

SPECIAL MEETING OF THE BOARD OF DIRECTION.

A special meeting of the Board of Direction to transact the regular business of the Society was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Friday, September 14, 1906, at 8:35 P. M.

Present: Messrs. Kennedy, Barnsley, Morse, Raymer and Secretary.

The resignation of John W. Hussey was accepted.

The deaths of John G. Lanning and Camille Mercader were reported.

The Secretary reported that he had secured seven literary magazines for the lounging room in exchange for the "Proceedings."

On motion the Secretary was directed to express to the officers of the Carnegie Steel Co. the thanks of the Society for the courtesies extended to them on their visit to the Isabella Furnaces September 8, 1906.

On motion the Secretary was directed to extend to the faculty of the Western University of Pennsylvania an invitation to hold their faculty meetings in the Board rooms of the Society for the remainder of the Society's fiscal year.

On motion the Philosophical Society of Pittsburgh was allowed the use of the rooms of the Society in which to hold their meetings the remainder of the fiscal year. The Secretary was directed to tell them that if they were able to contribute

anything to the Society in the way of rent, the same would be welcome.

The meeting adjourned at 10:20 P. M.

F. V. McMullin, Secretary.

MECHANICAL SECTION.

The regular meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, Fulton Building, Tuesday, October 2, 1906, at 8:00 P. M., Chairman L. C. Moore in the chair and 23 members and visitors present.

The minutes of the last meeting being in print their reading was dispensed with.

A paper on "Machine Shop Cost Accounts" was read by William Cunningham, Non-Member. The paper was discussed by Messrs. Moore, Berentsen, Danforth, Lane, Stucki and McGrew.

Meeting adjourned at 9:50 P. M.

A. A. Lane, Secretary M. S.

STRUCTURAL SECTION.

The regular monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, Fulton Building, Pittsburgh, Pa, Tuesday, September 25th, 1906, at 8:15 P. M., Chairman R. A. Cummings in the chair and 33 members and visitors present.

As the minutes of the last regular meeting had been printed, they were not read.

W. M. Judd, Member, read a paper on the "Construction of Coke Ovens."

The paper was discussed by Messrs. Diescher, Schellenberg, Morse, Barnsley, McDonald, Carroll and Stucki.

Meeting adjourned at 10:15 P. M.

G. H. Danforth, Secretary S. S.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

Vol. XXII NOVEMBER, 1906 No. 8

MONTHLY MEETING OF THE SOCIETY.

The 268th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Tuesday, October 16, 1906, at 8:00 P. M.

The meeting was called to order by Vice-President, J. K. Lyons, 106 members and visitors being present.

The minutes of the last meeting being in the hands of the printer, and there being no objection, their reading was dispensed with.

The report of the Board of Direction was read recommending eight applicants for membership.

On motion the Secretary was directed to cast the ballot of the Society for their election.

The Chair announced that the President had appointed the following members as a Nominating Committee to make nominations for officers for the ensuing year:

Morris Knowles, Chairman; J. N. Chester, W. C. Coffin, Charles Davis, S. B. Ely.

The paper for the evening, "The Pittsburgh Filtration Works," was presented by Morris Knowles, and was illustrated by slides from photographs made during the course of construction.

Following the paper a general discussion of the subject was participated in by Messrs. Winter, Knowles, S. A. Taylor, Cronemeyer, Flanagan and Schellenberg.

The Chair called attention to the large number present,

and expressed the pleasure of the officers of the Society at seeing such a meeting, as they regarded it as an endorsement of their action in moving into new rooms.

On Motion adjourned at 9:40 P. M.

F. V. McMULLIN,
Secretary.

NEW MEMBERS JOINED IN OCTOBER, 1906.

BARKER, CHARLES WHITNEY TILLINGHAST, 2nd Ass't. Engr. Bureau of Filtration. Wyebridge Club. Aspinwall, Pa.	Morris Knowles, Frederick E. Field, Maynard A. Tenne.
CRITCHLOW, PAUL NISBET, Draftsman, 506 Fifteenth Avenue, New Brighton, Pa.	Edwin F. Wendt. Herbert Henderson, J. E. Banks.
DONOVAN, RICHARD JAMES, Naval Architect. American Bridge Co., Pittsburgh. Pa.	R. Khuen, C. G. Dunnells, T. J. Wilkerson.
EHRMAN, SIDNEY, Ass't. on Eng. Corps, P. F. W & C. Ry., Baden, Pa.	E. E. Field, Edward Godfrey, John L. Carr.
GEORGE, HAROLD COULTER, Instructor in Mining Eng. and Mineralogy, Western University of Penna., Allegheny, Pa.	F. C. Phillips, Daniel Carhart, A. E. Frost.
KLOMAN, CHARLES ANTHONY, Draughtsman, 1842 Clark St. Extension, Pittsburgh, Pa.	F. L. White, J. P. Collins, J. K. Lyons.
MONROE, WM. THOMAS, Dealer in Lumber for Factory Bldgs., Diamond Bank Building, Pittsburgh.	J. E. Whittlesey, Lewis J. Affelder, Richard Khuen, Jr.
NEGRU, JACQUES, Mining Engineer, 215 Coltart Square, Pittsburgh.	G. W. Schluederberg. F. Z. Schellenberg, Jos. A. Shinn.
PORTER, HENRY TEGMEYER, Chief Engineer, B. & L. E. & Western Allegheny R. R., Greenville, Pa.	Geo. T. Barnsley, E. K. Morse, Emil Swensson.
PATTERSON, ROBERT FORBES, Assistant to Electrical Engineer, Pressed Steel Car Co., Beaver Falls, Pa.	F. E. McKee, Paul Hay, E. H. Haslam.
WILEY, BRENT, Commercial Engineer, Westinghouse Electric & Mfg. Co., 6326 Marchand St., Pittsburgh.	C. F. Scott, H. D. James. R. S. Feicht.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Saturday, October 6, 1906, at 8:00 P. M.

Present: Messrs. Kintner, Lyons, Knowles, Morse and Secretary.

The resignation of G. M. Campbell was accepted.

The following letter was presented by the Secretary:

Pittsburgh, Pa., Oct. 6, 1906.

Mr. President and Board of Direction.

Gentlemen: In January, 1905, the writer assumed the Secretaryship. Since that time there has been a business system successfully installed in the office, a Financial Policy has been put in force, the control of the Proceedings has been regained, we have moved into better rooms, the Library has been taken out of storage—the useless part disposed of and the good books placed upon the shelves—a Library Policy has been formulated, amended Charter drawn up, and new By-Laws written; so that the writer feels that his work as Secretary can be advantageously terminated at the end of the present year, and takes this opportunity of announcing that he will not be a candidate for re-election.

Truly yours,
(Signed) F. V. McMullin,

On motion the salary of the clerk, Miss Kaler, was increased to $60.00 per month.

On motion, it was decided to keep the rooms open until 10:00 P. M. Saturdays until further notice.

On motion the thanks of the Society were tendered to the H. J. Heinz Co., for the courtesies extended to the Society upon the occasion of their visit, Friday, Sept. 28, 1906.

On motion the meeting adjourned at 11:00 P. M.

F. V. McMullin,
Secretary.

SPECIAL MEETING OF THE BOARD OF DIRECTION.

A special meeting of the Board of Direction, to consider the question of the use of the rooms of the Society by other organizations, also to consider the new By-Laws, was held at the Fulton Building, Pittsburgh, Pa., October 10, 1906, at 8:15 P. M.

Present: Messrs. Kintner, Lyons, Knowles, Barnsley, Morse, Raymer and Secretary.

On motion, the President was empowered to appoint a committee, to meet with the committee appointed by the Pittsburgh Section of the American Chemical Society, and confer with them regarding the conditions under which the Section might meet in the Society's rooms.

On motion, the Board adopted the amendments to the new By-Laws submitted by the Secretary.

On motion, the Secretary was ordered to have the proposed new Charter and By-Laws printed and a copy sent to each of the past elected and present officers of this Society with an invitation to meet in conference with the Board upon the question, Tuesday, October 30, 1906.

On Motion the meeting adjourned at 10:30 P. M.

F. V. McMullin, Secretary.

SPECIAL MEETING OF THE BOARD OF DIRECTION.

A special meeting of the Board of Direction to consider proposed changes in Charter and new By-Laws, was held at the Fulton Building, October 30th, 1906, at 8:00 P. M.

Present: Messrs Kintner, Lyons, Knowles, Morse, Schellenberg; Past Presidents: W. G. Wilkins, Wm. A. Bole; Past Director, Richard Hirsch; Attorney S. B. Smith and Secretary.

Various amendments to the By-Laws and improvements in the language used were suggested and adopted.

Meeting adjourned at 11:00 P. M.

F. V. McMullin, Secretary.

CHEMICAL SECTION.

The 143rd regular monthly meeting of the Chemical Section of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Thursday, October 18th, 1906, at 8:15 P. M., with Dr. James in the chair and 25 members and visitors present.

Mr. J. R. Taggart addressed the meeting on the "Work of the Division of Bacteriology of the City of Pittsburgh."

After discussion the meeting adjourned at 10:15 P. M.

HARRISON W. CRAVER,
Secretary C. S.

STRUCTURAL SECTION.

The regular monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Tuesday, October 23rd, 1906, at 8:15 P. M., with Chairman R. A. Cummings in the chair and 20 members and visitors present.

Minutes of the last meeting were read and approved.

The Chair appointed the following members as a Nominating Committee to nominate officers for the year 1907:

E. K. Morse, Chairman,
Charles G. Schade,
Willibald Trinks,
C. P. Wagoner,
T. J. Wilkerson,

with instructions to report at the November meeting.

The paper for the evening, "Tests of Bricks," by Mr. Joseph A. Shinn, was read in the absence of the author by Mr. F. Z. Schellenberg. The discussion was participated in by Messrs. Starrett, Danforth, Schellenberg, Lynch, Whited, Muellenhoff, Judd and McEwen.

On motion adjourned at 9:22 P. M.

G. H. DANFORTH,
Secretary S. S.

OFFICERS FOR 1906.

President.
JULIAN KENNEDY.
Vice-Presidents.
S. M. KINTNER, J. K. LYONS.
Treasurer, A. E. FROST. Secretary, F. V. McMULLIN.
Directors.
MORRIS KNOWLES. E. K. MORSE.
GEO. T. BARNSLEY. A. R. RAYMER.

STANDING COMMITTEES.

Reception Committee.
MORRIS KNOWLES, Chairman.
J. M. CAMP. F. R. DRAVO.
RALPH CROOKER, Jr. E. H. HASLAM.
EMIL GERBER.

Program Committee.
F. Z. SCHELLENBERG, Chairman.
S. M. KINTNER, A. R. RAYMER, J. O. HANDY.

House Committee.
GEORGE T. BARNSLEY, Chairman.
D. W. McNAUGHER, WALTHER RIDDLE.

Library Committee.
D. ASHWORTH, Chairman.
G. W. SCHLUDERBERG. K. F. STAHL. HARRY J. LEWIS.

SPECIAL COMMITTEES.

Publication Committee.
E. K. MORSE, Chairman.
F. S. RICE. L. J. AFFELDER.

Finance Committee
J. K. LYONS, Chairman.
A. E. FROST. G. E. FLANAGAN.

Building Committee.
GEO. S. DAVISON, Chairman.
WM. METCALF. J. A. BRASHEAR.
THOS. H. JOHNSON. EMIL SWENSSON.

Committee on Timber Tests.
E. K. MORSE, Chairman.
J. A. ATWOOD, THOS. H. JOHNSON, F. Z. SCHELLENBERG,
GEO. T. BARNSLEY, HARRY J. LEWIS, EMIL SWENSSON,
J. N. CHESTER, FRANCIS S. RICE. WILLIS WHITED,
R. A. CUMMINGS, WM. L. SIBERT, T. J. WILKERSON.
RALPH CROOKER, Jr., WM. MARTIN.

CHEMICAL SECTION.
LAWRENCE L. ARNOLD, Chairman.
Vice-Chairman, JACOB A. MOHR, Secretary, HARRISON W. CRAVER.
Directors.
J. M. CAMP. HARRY E. WALTERS.

MECHANICAL SECTION.
L. C. MOORE, Chairman.
Vice Chairman, C. B. ALBREE. Secretary, A. A. LANE.
Directors.
H. H. ANDERSON.

STRUCTURAL SECTION.
ROBT. A. CUMMINGS, Chairman.
Vice-Chairman, W. M. JUDD. Secretary, G. H. DANFORTH.
Directors.
F. M. BOWMAN. RALPH CROOKER, Jr.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

Vol. XXII DECEMBER, 1906 No. 9

MONTHLY MEETING OF THE SOCIETY.

The 26th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Tuesday, November 20, 1906, at 8.10 P. M.

The meeting was called to order by Vice President J. K. Lyons, fifty members and visitors being present.

As the speaker of the evening wished to take a train and did not wish to abbreviate the discussion on his paper, and there being no objection, the regular order of business was postponed until after the reading of the paper.

F. N. Speller read a paper on Materials and Properties of Wrought Pipe, and illustrated the same with a number of lantern slides. The discussion was participated in by

S. B. Ely,
K. F. Stahl,
H. C. Babbit,
J. Vollkommer,
T. B. Lynch,
Richard Hirsch,
Morris Knowles,
H. C. Cronemeyer,
L. S. Starrett,
Edmund Yardley,
J. L. Klindworth,
Thomas H. Johnson,
Gerald E. Flanagan.

The Chairman read the following report of the Nominating Committee:

"Your Committee appointed to name officers for the year

1907 have carefully canvassed the situation and have to present the following candidates:

President, Samuel Montgomery Kintner,
Vice President, George Thomas Barnsley,
Treasurer, Albert E. Frost.
Directors for two years:—Robert Augustus Cummings, Walther Riddle.
Secretary, Edmund Yardley.

In order that there shall be available for voting by the Society two additional Directors, in case the new Charter and By-Laws should become operative at the time of the annual election in January, the Committee desire to present for consideration the names of two men for Directors, to fill the term of three years which would then become necessary and present for this purpose the names of Francis Z. Schellenberg, and James Otis Handy.

Respectfully submitted,
John N. Chester,
William C. Coffin,
Charles Davis,
Sumner B. Ely,
Morris Knowles, Chairman."

The Secretary then read the report of the Board of Direction recommending for membership 11 candidates.

On motion the Secretary was instructed to cast the ballot of the Society electing the applicants.

On behalf of the Reception Committee, Morris Knowles asked for an expression of opinion of the members present as to the best day of the week to hold the annual banquet, the choice seeming to lie between Thursday and Saturday. On a vote being taken, there were no votes in favor of Thursday, and twenty-two votes in favor of Saturday.

The printed report of the Board of Direction in regard to an amended Charter and new By-Laws was presented.

Morris Knowles moved the adoption of the Charter.

After considerable discussion the objection was made that

the call for the meeting announced that the matter would be presented at this meeting, but would be acted on at a special meeting December 5th.

F. W. Winter moved that inasmuch as notice has been sent out for a special meeting for final action on the Charter on December 5th, and in order that no legal question can possibly be raised, the Secretary be instructed to send out a special notice for a postponed meeting Monday, November 26, 1906, and in his notice call attention to the fact that it is to take the place of the meeting formerly announced for December 5th, this meeting to take final action on the Charter and also discuss the By-Laws.

At the suggestion of Morris Knowles the motion was amended by adding that the provisional adoption of the proposed By-Laws shall also be considered at the meeting next Monday evening.

F. V. McMullin,
Secretary.

SPECIAL MEETING OF THE SOCIETY.

A special business meeting of the Society to consider amending the Charter and the provisional adoption of the new By-Laws was held at the Fulton Building, Monday, November 26, 1906, at 8:35 P. M.

President Julian Kennedy was in the chair and thirty members were present.

George S. Davison offered the following resolution:

Resolved, That it is the desire of the corporators and legal voters of this Corporation to alter, amend, and improve the Articles of Incorporation thereof by the substitution of the Articles hereinafter set forth for the present Articles IV, V, VI, VII, VIII, IX, and X:

Article IV.

The offices of the said corporation shall be located in the city of Pittsburgh, Allegheny County, Pennsylvania.

ARTICLE V.

Said corporation shall exist perpetually.

ARTICLE VI.

The officers of said corporation shall be a President, two Vice Presidents, a Secretary, a Treasurer and six Directors. The Directors shall be elected for a term of three years, two of them being elected each year.

ARTICLE VII.

Said corporation is a corporation not for profit, and has no capital stock and no shares of stock.

It shall have power to take and hold property, real or personal, by devise, bequest or gift, either absolute or conditional. And it shall have power to acquire by purchase or in any other way, such properties, real or personal, not exceeding the amounts allowed by law, as shall be deemed needful, convenient or expedient in carrying out the purposes for which said corporation exists, and hold, use, lease, sell, convey, or otherwise dispose of, the same or any part thereof, and to employ the proceeds in furthering the interests and objects and carrying on the work for which it exists.

RESOLVED, That the necessary steps be taken, and that application be made to the proper court, by officers of this Corporation, to alter, amend and approve the Articles of Incorporation in accordance therewith.

Motion seconded by George T. Barnsley and on being put to vote was adopted unanimously.

The consideration of the new By-Laws was then taken up and they were discussed by:

Geo. S. Davison,	F. C. Phillipps,
Emil Swensson,	E. K. Morse,
Geo. T. Barnsley,	Ralph Crooker, Jr.,
Thos. H. Johnson,	L. P. Blum,
Morris Knowles,	Julian Kennedy,
C. Ludlow Livingston,	S. M. Kintner,
C. B. Albree,	C. F. Scott,
A. Stucki,	F. W. Winter,

On motion, the By-Laws were referred back to the Board with instructions to recast according to the sentiment expressed by the meeting, and that they be reported to a special meeting of the Society, December 12, 1906.

Meeting adjourned at 10:30 P. M.

F. V. McMullin,

Secretary.

NEW MEMBERS JOINED IN NOVEMBER, 1906.

BAILEY, GEORGE HENRY, Jr., Manager, Pittsburgh Office National Meter Co., House Building, Pittsburgh.	D. M. Howe, Morris Knowles, A. A. Hamerschlag.
BROWN, EDWIN CORNER, Chief Civil Engineer, Carnegie Steel Co., Carnegie Bldg., Pittsburgh.	J. K. Lyons, Geo. S. Davison, B. H. Taylor.
FLEMING, THOMAS, Jr., Draftsman, American Water Works & Guarantee Co., Pittsburgh.	Geo. W Biggs, Jr., J. N. Chester, J. B. McIntyre.
HEINUS, FREDERICK, Representative, Bartlett-Orr Press, New York, Fulton Building, Pittsburgh.	E. H. Haslam, C. C Stutz, W. G. Wilkins.
LIPSEY, THOMAS EUGENE LEARD, U. S. Junior Civil Engineer, Box 536, Beaver, Pa.	R A. Cummings, Wm. A. Christian, W. H. Chadbourn, Jr.
MAXWELL, LEVI HOUSER, Chief Draftsman, Schoen Steel Wheel Co., 51 Euclid Ave., Bellevue, Pa.	H. H. Anderson, A. Stucki, F. R. Jennings.
ROBERTS, HIRAM HALL, Draftsman, LaBelle Iron Works, Steubenville, Ohio.	William Forsstrom, Willibald Trinks, Samuel S. Posey.
SCOTT, JOHN KUHN, Draftsman, American Water Works & Guarantee Co. Pittsburgh.	J. N. Chester, Geo. W. Biggs, Jr. J. S. McBride.
WILSON, BURTON CLAY, Chief Electrician, Atlas Portland Cement Co., Catasauqua (Lehigh Co.) Pa.	A. W. Crouch, M. Greenwood, John W. Landis.

BOARD OF DIRECTION.

The reguar monthly meeting of the Board of Direction was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Saturday, November 10, 1906, at 8:00 P. M.

Present: Messrs. Kintner, Lyons, Knowles, Barnsley, and Secretary.

The following resignations were accepted:

Alston, Jr., Archibald,	Stone, Benjamin W.
Slocum, Alex. W.,	Taylor, Frank H.

The death of John H. McDonald was reported.

On motion the thanks of the Society were extended to the officers of the Carnegie Steel Company, the Bessemer Railroad and the Conneaut Dock Company, for the courtesies extended to the Society upon the occasion of their visit to Conneaut Harbor, Ohio, October 27th, 1906.

On motion the Secretary was authorized to employ a person to keep the rooms open Saturday evenings for one more month.

Mr. Knowles reported a number of amendments to the new By-Laws which, on motion, were adopted, and the Secretary was directed to have the revised copies of the By-Laws ready for distribution at the meeting of the Society November 20th, and to notify the Society that the subject would be presented at that meeting for the first consideration, and be presented for final action of the Society at a special meeting to be held December 5h, 1906.

On motion adjourned at 9:50 P. M.

Approved. F. V. McMullin,
Secretary.

CHEMICAL SECTION.

The 144th regular meeting was held in the Fulton Building, November 22nd, with the Pittsburgh Section of the American Chemical Society, Dr. James in the chair and forty-three members and visitors being present.

The chairman appointed the following nominating committee to nominate officers for 1907:

K. F. Stahl, F. C. Phillips,
H. E. Walters.

Dr. W. F. Hillebrand addressed the meeting on the work of the Chemical Laboratories of the United States Geological Survey. After discussion the meeting adjourned at 10 P. M.

HARRISON W. CRAVER,
Secretary, C. S.

MECHANICAL SECTION.

The regular monthly meeting of the Mechanical Section was held at the Fulton Building, Tuesday, November 6th, 1906, at 8:30 P. M.

Chairman L. C. Moore in the chair and seventeen members and visitors present.

Mr. J. D. Underwood read a paper on "The Pitometer as Used in Waste Water Investigations." The paper was discussed by Messrs. Schellenberg, Muellenhoff, Lane, Flanagan, Stucki, Babbit, Moore, Leland and Brosius.

On motion meeting adjourned at 9:30 P. M.

A. A. LANE,
Secretary, M. S.

STRUCTURAL SECTION.

The regular monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held Tuesday evening, November 27th, 1906, at the Society's rooms, Fulton Building, Pittsburgh, Pa.

Thirty-three members and visitors present.

Meeting called to order by Chairman R. A. Cummings, at 8:12 P. M.

Minutes of the last meeting were read and approved.

The Secretary read a communication from E. K. Morse, regarding the dissolution of the Section. The question was discussed by: Barnsley, Engstrom, Lynch, Whited, Stucki, Khuen, Shinn, Lyons, and Muellenhoff.

On motion, the question of dissolution of the Section was referred to the Directors of the Section, with a request to report at the next meeting.

The paper of the evening, "Modern Shop Practice from an Inspector's Standpoint," by D. W. McNaugher, was read by the secretary. The discussion which followed was participated in by: Messrs. Gerber, Khuen, Godfrey, Shaw, Whited, Lyons, Canaday, Stucki, Muellenhoff, and McEwen.

On motion meeting adjourned at 10:08 P. M.

G. H. DANFORTH,
Secretary, S. S.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

VOL. XXII JANUARY, 1907 No. 10

MONTHLY MEETING OF THE SOCIETY.

The 270th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Tuesday, December 18, 1906, at 8:00 P. M. Vice President S. M. Kintner in the chair and 40 members and visitors present.

The minutes of the last meeting being in print and there being no objection their reading was dispensed with.

On motion the new By-Laws were approved.

Mr. F. Z. Schellenberg then read a paper before the Society on "Our Coal," which was discussed by the following gentlemen:

Thomas H. Johnson,	C. Ludlow Livingston,
J. P. Leaf,	Jacques Negru,
Edmund Yardley,	H. C. Babbitt,
G. E. Flanagan,	S. A. Taylor,
A. E. Duckham,	F. Z. Schellenberg.

On motion meeting adjourned at 10:00 P. M.

F. V. McMULLIN,
Secretary.

NEW MEMBERS JOINED IN DECEMBER, 1906.

JOHNSON, DION LYNN, Chemist, Carnegie Steel Co., Duquesne, Pa.	J. M. Camp, A. N. Diehl, C. H. Rich.
MOOL, HARRY WILLIAM, Draftsman, American Bridge Co., Perrysville Ave., Ben Avon, Pa.	J. K. Lyons, A. L. Lee, M. A. Preston.
SCHAAF, ADOLPH JACOB, Chief Engineer, Monongahela River Consolidated Coal & Coke Co., 130 Merrimac St., Pittsburgh, Pa.	J. N. Coleman, N. J. Affelder, Thos. M. Rees.
WALKER, ROBERT A., Manager of the Iron Age. 1201 Park Building, Pittsburgh, Pa.	J. M. Camp, Emil Swensson, N. C. Wilson.
WOOD, JOHN HUTCHINSON, Asst. Eng., 6344 Marchand St., Pittsburgh, Pa.	J. D. Underwood, Willis Whited.

SPECIAL MEETING OF THE SOCIETY.

A special meeting of the Society to consider the report of the Board of Direction regarding the rewritten By-Laws, was held at the Fulton Building, December 12th, 1906, at 8:15 P. M.

Vice President S. M. Kintner in the chair with 18 members present.

The new By-Laws, as rewritten by Attorney Sion B. Smith, under the supervision of the Board of Direction, were reported and read Section by Section; various amendments being submitted by the different members were discussed and acted upon.

The entire new By-Laws were, on motion, approved and ordered submitted to the Society for adoption at the regular monthly meeting, December 18, 1906.

On motion meeting adjourned at 10:30 P. M.

F. V. McMullin,
Secretary.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Monday, December 10, 1906, at 8:00 P. M.

Present: Messrs. Kintner, Lyons, Barnsley, also by special invitation to discuss the new By-Laws, Thos. H. Johnson, K. F. Stahl, F. C.Phillips, Willis Whited, Ralph Crooker, Jr., Edmund Yardley, Attorney Sion B. Smith and the Secretary.

The following resignations were accepted:

Bennett, Edward,	Posey, Samuel S.,
Eckert, Edward W.,	Price, Chas. B.

On motion it was decided to charge the Pittsburgh Section of the American Chemical Society a rental of $5.00 per night for the use of the Society's auditorium for holding their meetings, beginning with January, 1907.

On motion the Secretary's action in disposing books and pamphlets in the Library, either by sale or exchange, was approved.

The letter to delinquent members, submitted by the Secretary, was approved and ordered sent to all who had not paid dues to 1907.

The subject of By-Laws was then brought up for discussion and a number of amendments to the same produced by Mr. Barnsley and Atorney Sion B. Smith were discussed and approved.

Meeting adjourned at 11:00 P. M.

F. V. McMullin,
Secretary.

STRUCTURAL SECTION.

A special meeting of the Structural Section was held at the Society's rooms, Fulton Building, Monday, December 17, 1906, at 8:20 P. M.

The meeting was called to order by Chairman R. A. Cummings, 13 members and visitors being present.

The object of the meeting being

For further consideration of the question of disbanding the Section and to receive the opinion of the Directors of the Section on this question;

Also

To receive report of Nominating Committee as to officers for the ensuing year in case the Section should not be abandoned.

The subject was discussed by Messrs. Crooker, Whited, Affelder, Danforth, and Muellenhoff. Owing to so few being present, a vote could hardly be considered as representative of the Section, and the Secretary was instructed to report the result at the January meeting of the Section.

Mr. E. K. Morse, Chairman of the Nominating Committee, then submitted his report, placing nominations for the following officers for 1907, subject to Section being continued:

Richard Khuen ..... Chairman.
E. W. Pitman ..... Vice Chairman.
A. E. Duckham ..... Secretary.
L. J. Affelder ..... Director.
W. M. Judd ..... Director.

On motion meeting adjourned at 8:44 P. M.

G. H. DANFORTH,
Secretary S. S.

CHEMICAL SECTION.

The 145th regular meeting was held with the Pittsburgh Section of the American Chemical Society in the Fulton Building, Pittsburgh, Pa., December 20th, 1906.

The meeting was called to order at 8:30 P. M., Dr. James in the chair and 27 members and visitors present.

The minutes of the last meeting were read and approved.

Dr. K. F. Stahl, Chairman of the Nominating Committee, reported the following nominations for 1907:

C. H. Rich ..... Chairman.
C. B. Murray ..... Vice Chairman.
Harrison W. Craver ..... Secretary.
H. C. Babbitt ..... Director.
George O. Loeffler ..... Director.

Mr. Alfred Sang addressed the meeting on the "Industrial Outlook for Physical Chemistry." After discussion, the meeting adjourned at 10 P. M.

HARRISON W. CRAVER,
Secretary C. S.

PROCEEDINGS OF THE
ENGINEERS SOCIETY
OF WESTERN PENNSYLVANIA

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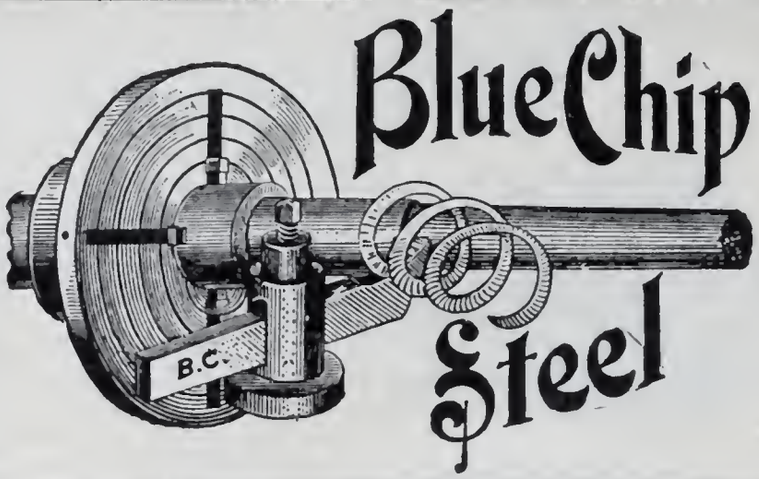

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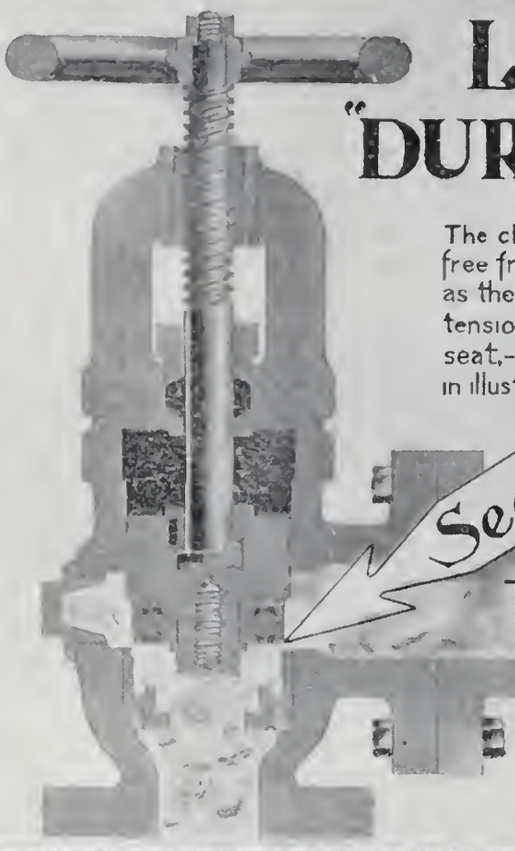

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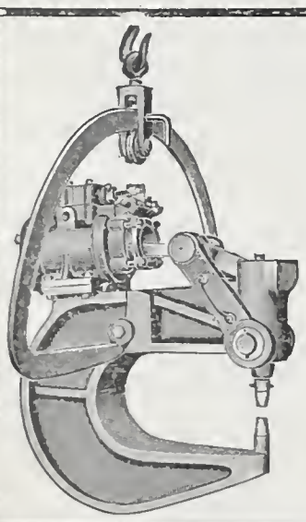

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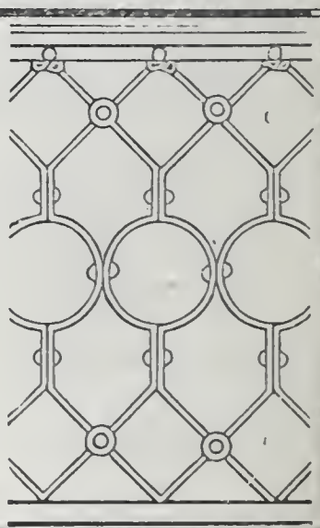

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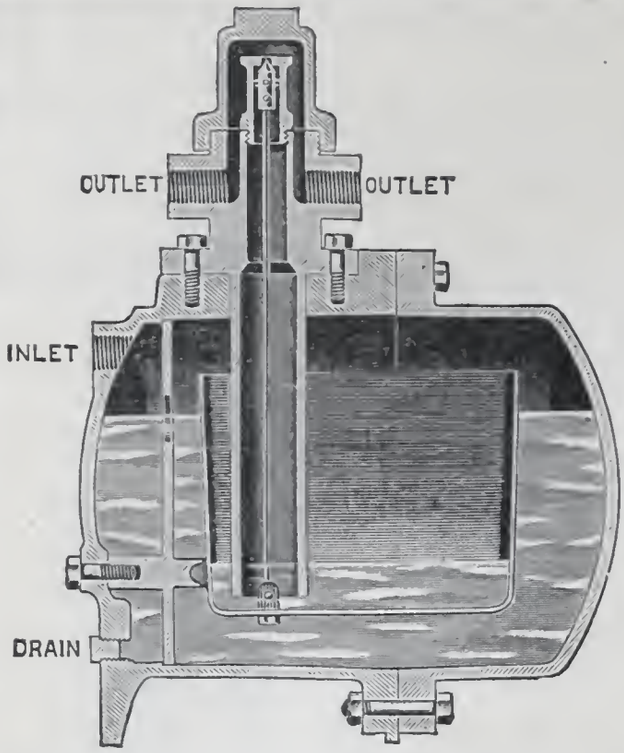

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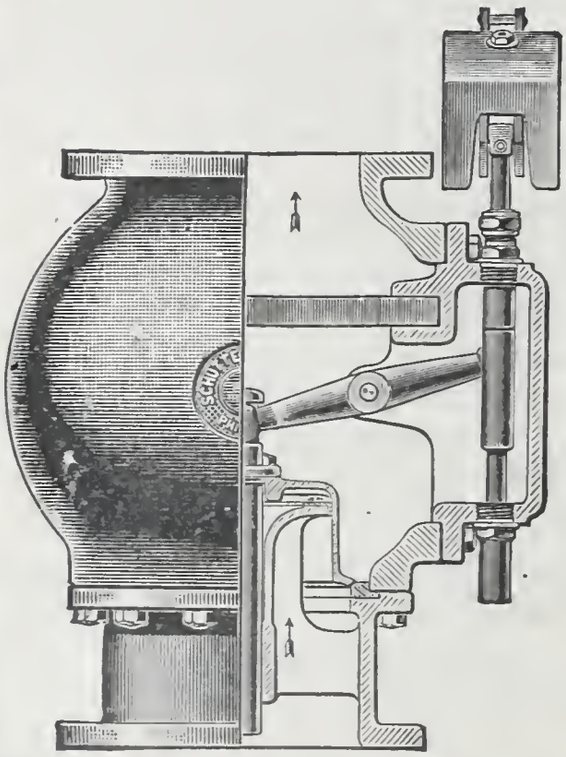

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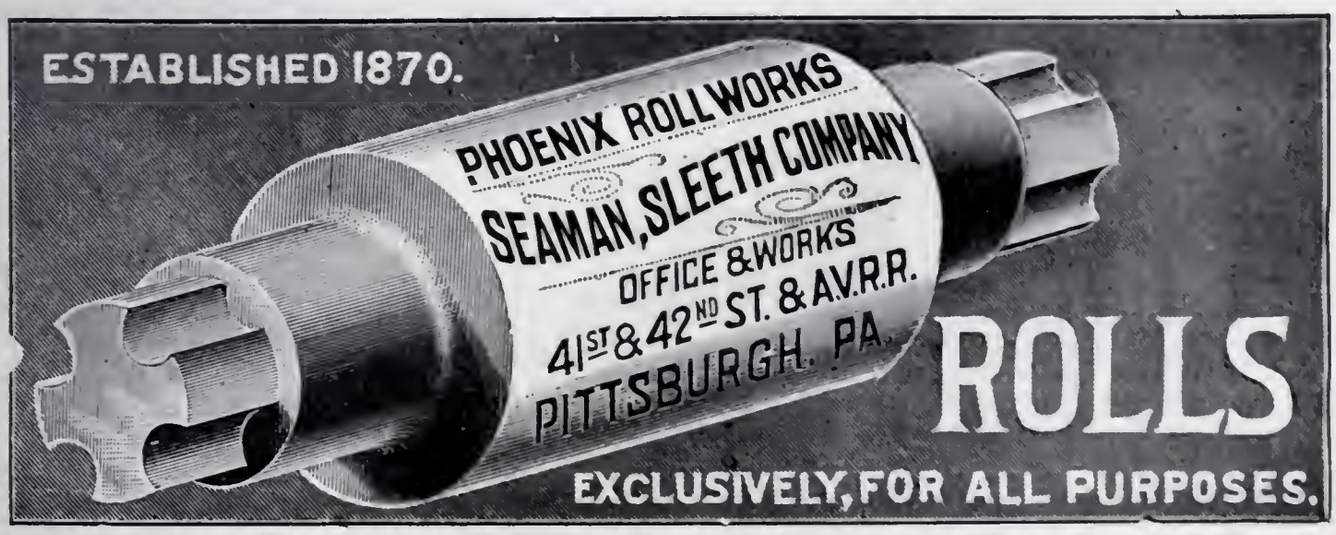

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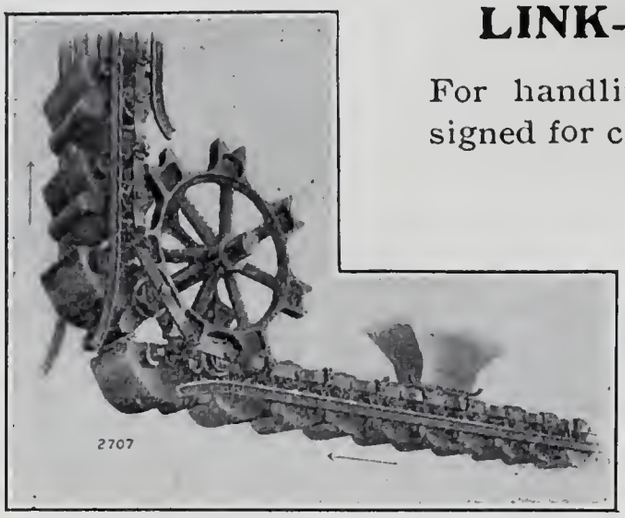

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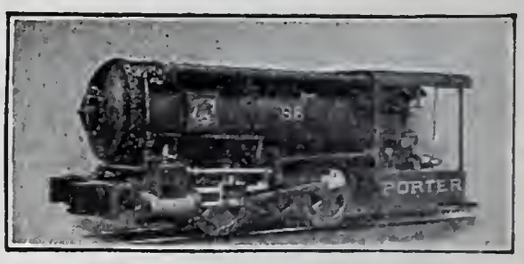

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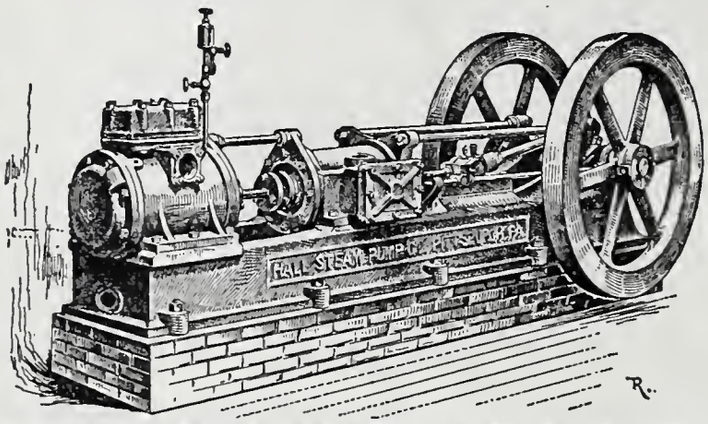

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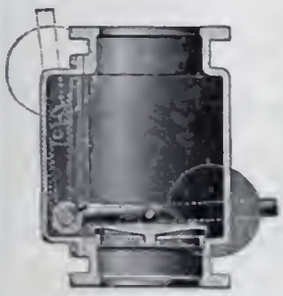

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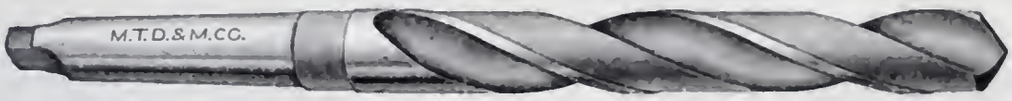

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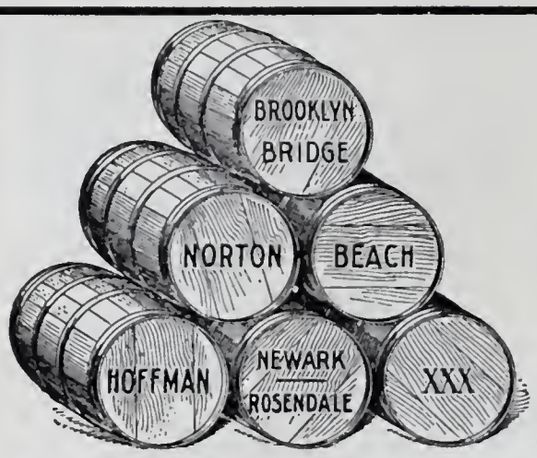

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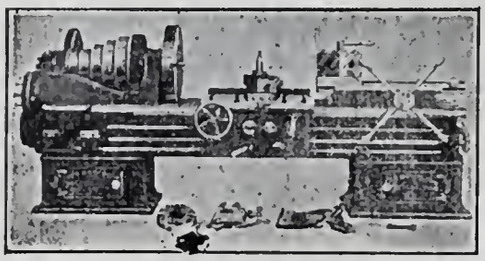

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Schellenberg, F. Z.
Cummings, Robert A.
Hindman-Henderson Co.
Duckham, A. E.

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Smith, R. L.
Kennedy, Julian
Swensson, Emil.
McGrew, J. & E.
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Kennedy, Julian
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Smith, R. L.

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Help—Technical.
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